PHOTOVOLTAIC INSTALLATION IN THE UNIVERSITY OF PAVIA

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RESUMEN

El presente proyecto denominado: "Instalación fotovoltáica en la universidad de Pavía", se trata de un estudio económico e ingenieril para conocer la viabilidad de la instalación, ubicada en el departamento de Ingeniería en la universidad de Pavía (Italia). Con el objetivo de reducir el consumo de combustible para la calefacción y la producción de electricidad y energía a partir de recursos renovables .

El documento se divide en 5 capítulos donde se recogen los siguientes aspectos:

Capítulo 1. Caso de Estudio:

Localizado en el Polo Cravino, concretamente en la azotea horizontal del edificio en forma de "L" del departamento de Ingeniería que consta de 7 plantas de 3,10m, pero que está distribuida a dos niveles intercalados, con una altura total de 15,4 metros. Situado al NE de Pavía, a las afueras de la ciudad.

La **producción de energía fotovoltaica** obtenida es elegida en relación a las necesidades del usuario, a su consumo de energía y a las condiciones de radiación solar en Pavia. Constituyendo la mayor limitación, la financiación económica ya que se disponen de espacio suficiente para albergar todos los módulos. Y la colocación de paneles es idóneas para evitar cualquier tipo de sombra que pueda reducir la obtención de energía.

El **posicionamiento óptimo** de la instalación sería hacia el sur con una inclinación de los módulos igual a la latitud del lugar. Sin embargo, la orientación de la universidad y la geometría de la cubierta no permite estos objetivos a alcanzar, a menos que se invierta alto capital en estructuras de apoyo específicas por lo que no resultaría rentable económicamente. Por lo tanto, los paneles fotovoltáicos se han montado en el sur-este de la azotea del edificio con una inclinación de 30 °. Ángulo fijado por motivos de seguridad y coste económico y que hemos calculado gracias a la comparación entre diversos software solares fotovoltáicos como: PV-FChar, PVSYST 4.36, Solarius-PV considerando como principales objetivos : obtener la máxima radiación solar, cubrir la mayor superficie disponible e invertir los mínimos costes.

Conexión: Se encuentra conectada a la red pública de la distribuidora local de electricidad cercana al punto de entrega. Optando finalmente por una instalación de 39,6 kWp.

Componentes: conectado en paralelo a la red está constituido por:

- Campos conectados en paralelos, compuestos de un total de 240 módulos fotovoltáicos de silicio poli-cristalino, marca: Mitsubishi: PV-MF165EB4. Que garantiza una conversión con la eficiencia de alrededor del 93%.
- Estructuras de apoyo en forma triangular con ángulo de 30º fijo, que permite sostener bloques de dos módulos expuestos verticalmente para optimizar espacio.
- Convertidor estático de corriente directa / corriente alterna. La función de los inversores es convertir la electricidad estática de una entrada de CC en una de salida de CA. Los inversores electricidad están conectados al árbol de los 400 V circuito de fase en paralelo con el ENEL. .
- Cable de votantes y el cableado correctamente calculado.
- Sistema de la masa a la tierra


Ubicación de paneles en el techo: se distribuyen en cinco línea:

- *1ª línea*: la más cercana al filo de la terraza que da a la puerta principal. La longitud es de 67,87 metros por ello implantamos 72 módulos, y entre ambos hay un espacio libre de 4 m para cualquier tipo de manipulación.
- *2ª y 3ª línea*: Son las líneas más largas, donde hay 81 paneles.
- *4ª y 5ª línea :* Corresponden a las partes más estrechas ubicando únicamente 4 paneles. Situadas en el espacio más cercano al edificio donde están las escaleras.

Finalmente, los módulos de la matriz están interconectados en tres grupos de 80 paneles, conectados en paralelo a su correspondiente inversor. Y cada uno de estos grupos de 80 paneles también consiste en 5 sub-grupos de 16 módulos en serie que se encuentran entre sí en paralelo.

Tipología de conexión: La instalación estará conectada a la red de distribución de la energía eléctrica de acuerdo con el régimen de transferencia pura de la energía. La red será atado en el trámite trifásico, respetando la normativa en particular relacionada con el ENEL, disposiciones para la la conexión de la planta a la red pública.
La producción de energía fotovoltáica es utilizado directamente por la universidad o para alimentar la red en función de la potencia producida y de la electricidad consumo. Esto permite que la energía eléctrica que no se consume directamente se intercambie. Siendo particularmente importante para este tipo de edificio, en el que durante el mejor período de captación y por lo tanto de producción máxima (verano) hay una demanda eléctrica mínima.

Sistema fotovoltáico principales características:

- Potencia nominal: 44 kWp
- Superficie ocupada neta: 303 m^2
- Circuito abierto con voltaje de salida de 213 V CC y un corto circuito de corriente de salida de 4,4 A.

Medición y Control: La salida del sistema se controla con los inversores PV por un sistema de adquisición de datos controlada por un programa de medición y análisis (Sunny Boy Control Plus) montado en un PC. El sistema de adquisición de datos y el ordenador se comunican entre sí por medio de un RS232: protocolo de comunicación, cuyos datos medidos son:

- Potencia y tensión eléctrica de cada variedad;
- Cada fase actual de alimentación a la red;
- Cada fase de la energía eléctrica alimentada a la red.

La **intensidad de la radiación** solar directa diaria, recibida por el sistema se ha calculado conociendo el sistema de inclinación, la orientación y las coordenadas geográficas de Pavía.
En condiciones de cielo despejado, se reciben alrededor de 3,5 kWh/m^2 del día solar global con irradiación horizontal frente al 3,8 kWh/m^2 que sería recibido en la orientación óptima.

Integración arquitectónica: Consiste en combinar la función clásica de los módulos fotovoltáicos con la función de un elemento de la construcción integrada. Para minimizar su impacto visual, la tecnología ha evolucionado y ahora se implantan los módulos diseñados y producidos para proporcionar la integración idónea para la producción de energía y fomentar la sostenibilidad mediante la estética moderna, ecológica y vanguardista. Con referencia a la norma UNI 8627 "Sistemas de cobertura".

Capítulo 2. PVSYST 4.36: SOFTWARE FOTOVOLTÀICO:

Gracias a este paquete software hemos comparado resultados teóricos y prácticos sobre datos meteorológicos y solares obtenidos por otros medios, libros e diversos software. Para así mejorar el estudio, diseño y dimensionamiento de la instalación.
PVSYST v4.6 ofrece 3 niveles para el estudio del sistema, aproximadamente correspondientes a las diferentes etapas en las que se estructura el desarrollo de un proyecto real:

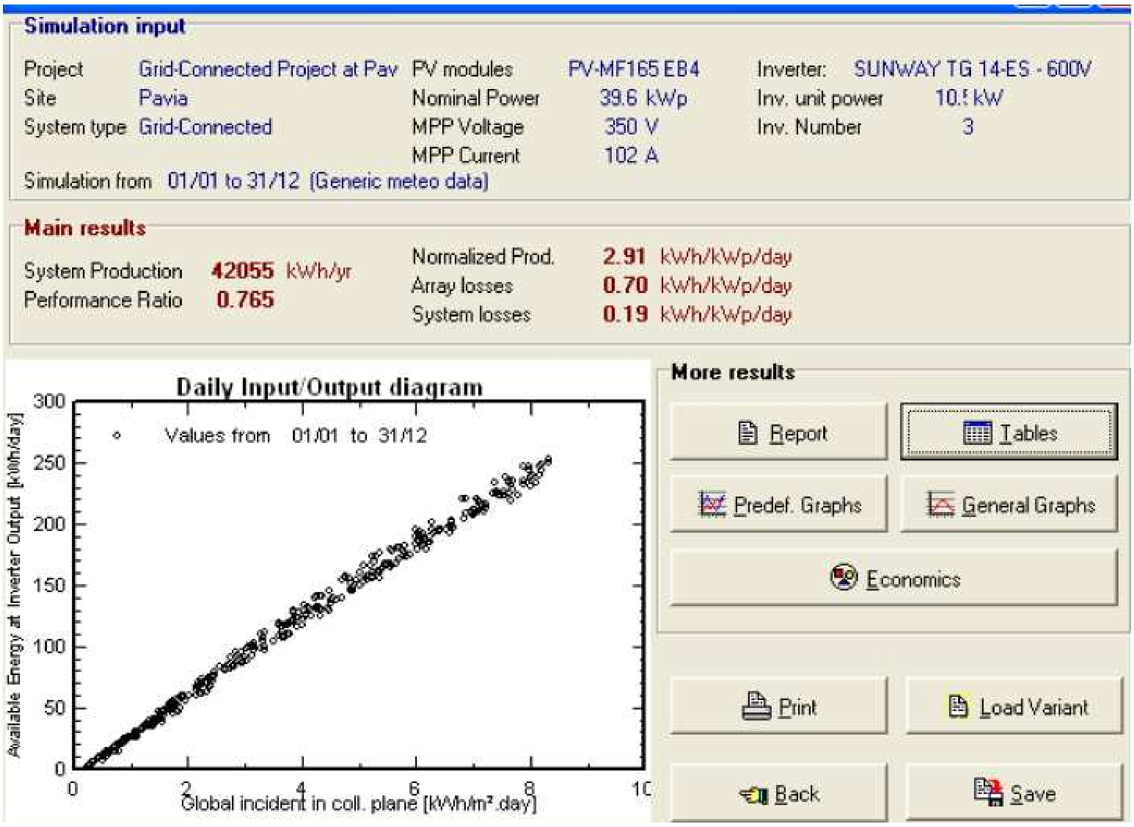
- **Diseño preliminar**
- **De Diseño de Proyectos**
- **Herramientas**

En el **Diseño Preliminar** se realiza una simulación a grandes rangos, pues únicamente definimos la localización y el tipo de sistema para obtener el resultado, que describe las características generales del sistema sin profundizar en los especificaciones de cada uno de los componentes. Los cuales deberíamos definir posteriormente a través de los consecutivos niveles.

La opción más útil es sin dudad el **Diseño del proyecto** pues propone realizar un minucioso diseño del sistema y análisis de rendimiento mediante simulaciones detalladas por hora.
Estos se organizan en el marco de un proyecto, que básicamente tiene la situación geográfica y datos meteorológicos por hora. Optimización y análisis de parámetros se puede realizar a través de simulación de carreras diferentes, denominadas variantes.

Procedimiento:

- Pudiendo elegir entre sistemas fotovoltáicos de: conexión a la red, independiente, de bombeo y DC-red (transporte público) en nuestro caso es claramente conexión a red: "Grid-connected"
- En primer lugar se definir el proyecto a través del "Proyecto botón de la variante". También puede recuperar un proyecto ya existente a través del menú "File".
- Para cada proyecto definimos su ubicación geográfica y Meteorológica con posibles datos albedo, para poder construir un sistema de variantes diferentes (tanto como sea necesario).
- Para cada variante, definimos su orientación. Y las propiedades del sistema (herramientas) .
- El programa verifica la coherencia de todos los parámetros, y produce "Advertencias" con destellos naranjas que incida que es aceptable para la simulación o rojos que remarca la prevención de la simulación.
- Cuando estén disponibles todos los parámetros bien definidos, comienza la simulación y una vez completada se accederá a los resultados de diálogo y su puede consultar los principales resultados en el documento "Informe".
- Lo más importante es que después de la simulación, cada variante se puede guardar, definiéndola con una descripción significativa, para usarla ante otras comparaciones.



Por último, en el apartado de **herramientas** obtenemos toda la base de datos de Meteonorm, que resume los datos meteorológicos de alrededor de 7.7 sitios del mundo. Concretamente en nuestro proyecto definimos: *latitud*: 45 ° 11'36 "Norte, *longitud*, 9 ° 9'21 "Este; y altitud: 80 metros sobre el nivel del mar y zona horaria: 1 .Y los datos mensuales de irradiación, temperatura y velocidad del viento:

Así como las coordenadas geográficas : mostrando la geometría de la irradiación solar y "Clear-Sky" en el plano. Donde se puede elegir la inclinación óptima: 30º y el ángulo azimut: 0º, haciendo una comparación de la intensidad luminoso para optimizar la energía de sol capturada según sean los días soleados o nublados.

Por lo que en rangos generales esta tercera parte de PVSYST da acceso a los siguientes temas:

- *Meteo de base de datos:*

- Sitios geográficos: los parámetros geográficos de cerca de 200 sitios en el mundo, incluyendo los datos mensuales de meteo (horizontal y global de la temperatura).
- Synthetic hora generación de datos: para generar meteo de datos horarios de síntesis de los datos anteriores al mes.
- Importación de datos desde bases de datos externas Meteo: permite el uso de los datos meteo de las bases de datos más populares.
- Importar archivos ASCII Meteo: permite importar los datos meteo hora o por día.
- Meteo Tablas y gráficos: la visualización y el análisis de la herramienta de gran alcance para los archivos de datos meteo por hora.

- *Base de datos de componentes PV:*

- Módulos fotovoltaicos,
- Inversores Grid,
- Pilas,
- Bombas,
- Reguladores para sistemas autónomos
- Reguladores (controladores) para los sistemas de bombeo
- Generadores (grupos electrógenos),
- Lista de vendedor.

- *Caja de herramientas Solar:*

- Gráfico / Tablas de parámetros solares: muestra la geometría de la irradiación solar y Clear Sky
- El comportamiento eléctrico de las series de PV: invertir características de los módulos fotovoltaicos, desfase, matriz con células de sombra, conjunto heterogéneo.
- Meteo cálculo mensual: la evaluación rápida utilizando la base de datos meteo sitio geográfico, con el horizonte, la inclinación, los cobertizos y el sol escudos, los efectos de la IAM.
- Factor de la transposición: la optimización de la orientación del campo y la herramienta de evaluación.
- Optimización de funcionamiento de tensión.

- *Medida de análisis de datos:*

- Importación de ficheros de datos ASCII medida:
- Archivo de transformación: herramienta técnica para la fusión y el corte PVSYST medido archivos de datos.

Capítulo 3: Estudio económico

Financiación del estudio PV : La instalación de sistemas fotovoltáicos en la superficie de nuestro edificio hace posible combinar la producción de energía eléctrica con otras funciones de las estructuras del edificio. Conectados a la red de sistemas fotovoltaicos representan una solución fiable para el suministro de electricidad en los edificios, de hecho, los costes de inversión se reducen porque no se necesita de la tierra, la estructura de apoyo es menos costoso, y las pilas de almacenamiento no son necesarios. Además la electricidad se genera en el punto de uso para evitar la transmisión y pérdidas de distribución.

Este capítulo contiene el análisis de la rentabilidad de la instalación teniendo en cuenta la situación económica y financiera de Italia en el año de la inversión (2009). En un contexto de crisis económica en la que las instituciones financieras quieren evitar cualquier riesgo y por tanto muy pocos proyectos financiados exigen un rendimiento alto y seguro. Por eso es necesario, que una institución financiera o de fondos de inversión adquirirá la instalación y que contribuya en el derecho de explotación de la instalación a cambio del pago de rentas de arrendamiento durante un plazo determinado, que en nuestro proyecto asciende a 12 años. Con la conclusión de que la institución financiera tiene la opción de comprar la instalación pagando un precio determinado, devolverlo al promotor o renovar el contrato.

Debido a esto, se han beneficiado del Arrendamiento de la "Banca Popolare di Vicenza" para estimular la inversión con una cobertura de hasta el 100% del valor de la instalación. Gracias a la creación desde julio de 2008, del "Crédito Solare ", una nueva línea de inversión crediticia sin garantía y cuyas hipotecas son de hasta el 100% del coste de la adquisición e instalación de la planta con tarifas atractivas. Con un plazo máximo de 20 años con el objetivo de equilibrar el porcentaje de la financiación y los beneficios resultantes de los incentivos en la cuenta de energía. El arrendamiento es una opción para las empresas que no se basan en el capital de inversión necesario para adquirir un activo fijo que representa una fuerte inversión de dinero usando como un mecanismo de financiamiento alternativo frente a e innovadoras para un crédito bancario simple ya que en este una parte está inmersa la ventaja de la sesión de uso.

Programa de apoyo italiano: En la Orden Ministerial a fecha: 19 de febrero 2007 se definen los criterios que proporcionen incentivos para la generación de electricidad mediante plantas solares fotovoltáicas. Esta tarifa varía en función de la capacidad de la planta (1 a 3 kWp, del 3 al 20 kWp y más de 20 kWp) de acuerdo a la tipología de la instalación fotovoltáica (plantas de energía que están integrados o no en los edificios y los sistemas fotovoltáicos basados en tierra). El incentivo es válido durante un período de 20 años y varía de 0,49 € / kWh, a 0,36 € / kWh, para no integrados y basados en tierra de sistemas fotovoltáicos, más de 20 kWp instalado en 2007- 2008. En nuestro proyecto al tener como año de posible ejecución y desarrollo: el año fiscal 2009. Y de la misma manera que la prima media se ha establecido como referencia por KW producido en régimen especial con la tecnología fotovoltáica y regulada por la "Conto Energia" (DM 19/2/2007) entre el primer trimestre de 2009, siendo esta de 0.392 € / kWh .
De esta forma, el crédito se obtendrá a 20 años, con un año de carencia, en la que se abonará la parte proporcional a la institución financiera o grupo de inversión. En el contrato antes mencionadas, se negociará el interés de salida aplicable. Para proporcionar un coeficiente de seguridad para el desarrollo del proyecto, diciendo que se fija en 6,3% (Euribor el primer año + el diferencial).

Después de una reducción fiscal se fija en 5% en 2010, un 4% en 2011 y un 3% en 2012. A partir de entonces el año antes mencionado ningún tipo de reducción fiscal que existe.

La producción estimada específicas para la instalación fija, en Pavía y con la tecnología se detalla en el primer capítulo y correspondería a 420,550 años kWh / 39,6 kWp instalada = 1,065 kWh / kWp después de un año. También se aplica un factor de pérdidas de energía estimado en 0,08% después de un cada año.

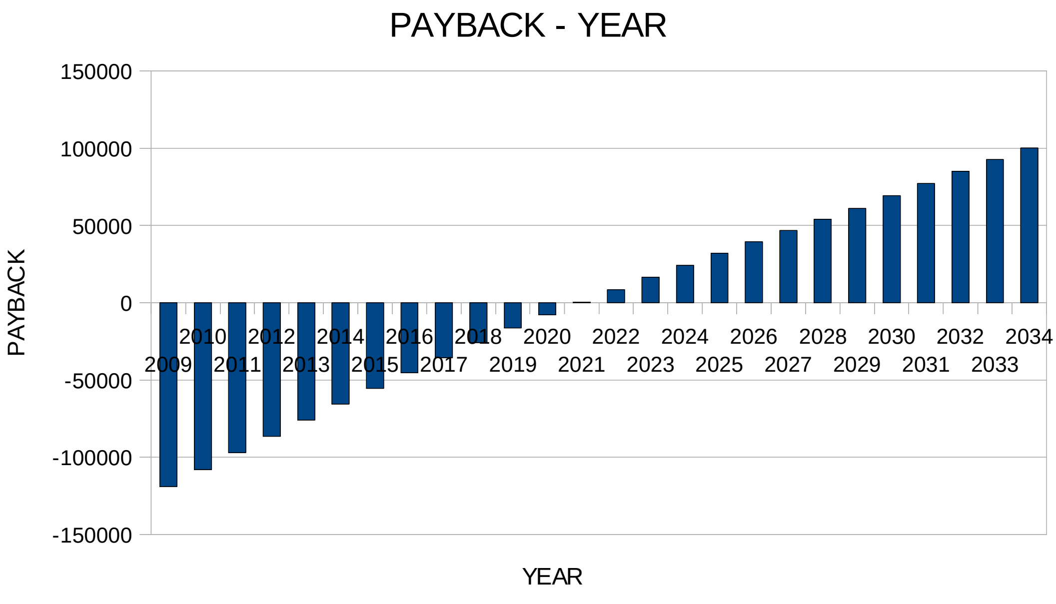
El precio total de acuerdo al **presupuesto de la instalación fotovoltáica** estudiado es 166.906 € que se divide a 39, 6 kWp instalado y de esta forma hemos obtenido el precio unitario de 4,20 € / Wp. Sin olvidar que todos los equipos instalados tendrán que presentar una garantía de 10 años, por lo que las reparaciones realizadas durante este período se encargará el fabricante.

En la **Inversión prevista** es necesario distinguir que el proyecto presenta un VPN de 100.098 € y un I.R.R. de 12,03%, con la estimación de 20 años de retorno de la inversión. Donde también se presenta la totalidad de los gastos e ingresos, así como los intereses a disolvente y el total a cuenta de la desgravación fiscal.

Gracias al **V. A.T**. :El análisis económico demuestra que, con los precios reales de los paneles fotovoltáicos estándar, en una planta de energía fotovoltaica en Italia exige un tiempo máximo de aproximadamente 16-17 años de reembolso a partir de inversión, dependiendo de la ubicación, el tipo y la calidad de panel y en el tipo de montaje. En Italia, un tipo de IVA 10% (ya reducido del IVA se refiere tasa "normal" que asciende al 20%) se agrega a cualquier producto relacionado tanto con la energía vendida por los proveedores de energía a clientes particulares, como a los paneles o instalaciones fotovoltáicas. El problema son tanto para las organizaciones públicas como municipios, provincias, etc que en Italia no tiene ninguna compensación del IVA.

Entre los **Gastos de explotación** ineludiblemente se encuentran los gastos de "leasing" (saldo actual del préstamo y el "Principal Leasing" (el reembolso anual de los préstamos), los intereses anuales de los préstamos, los gastos de cambio (debido al mantenimiento de la planta).

Por último, se obtiene el **Cash flow y retorno de la inversión** analizaron 25 años. La recuperación simple es una medida de la viabilidad económica que se interpreta como el número de años que una inversión tiene que pagar por sí mismo. Es decir, es igual al coste neto para el usuario después de todos los incentivos , dividido por los ahorros de primer año . Obteniendo:



Capítulo 4. Estudio Ambiental .

La energía solar constituye una de las piedras angulares de soluciones de energía alternativa limpia, y con las dificultades de los combustibles fósiles cada vez más grandes por el día, puede representar una solución viable a los problemas energéticos del mundo. Su impacto ambiental constituye uno de sus puntos de venta principal, y la más eficaz que pueda funcionar, mejor sus posibilidades de sustituir los combustibles fósiles como fuente principal de energía. Aunque en gran medida positivo, el impacto ambiental de la energía solar puede ser sutil y su efecto general deben ser cuidadosamente considerados como nuestros esfuerzos para explorar su potencial de avanzar hacia adelante.

Para hacer frente a estos problemas, este documento presenta una visión general de Impacto Ambiental. Evaluamos las intrusiones del medio ambiente con el fin de mejorar las soluciones con las nuevas innovaciones tecnológicas y buenas prácticas en los sistemas de poder en el futuro. El estudio proporciona la carga potencial para el medio ambiente, que incluyen el ruido y la intrusión visual, las emisiones de gases de efecto invernadero, contaminación del agua y del suelo, consumo de energía, los accidentes de trabajo, el impacto sobre los sitios arqueológicos o en los ecosistemas sensibles, socioeconómicos negativos y positivos efectos económicos.

El objeto de este estudio será de la eliminación de los daños que la construcción de las instalaciones pudieran ocasionar, así como obtener el oportuno informe favorable de Energía y Medio Ambiente de Lombardía, a fin de obtener la correspondiente autorización administrativa de la Sede Central y de la construcción licencia.

De acuerdo a la vida útil de la instalación: 25 años, las pérdidas de cada año y la potencia instalada es 42,773 kWh, gracias al programa Solarius PV: que recoge la información de fuente fiable, ENEL 2006 con su variación a 2009 y sabiendo que:
FET: es una unidad convencional de uso común en " bilanco enérgica" que expresar en una unidad común de medida para todas las fuentes de energía. Estipulando en este caso como factir de conversión MWh en TEP 0,22 (TEP/MWh)

Lo que permitiría ahorrar 21.216 toneladas de CO_2/to, 39,78 tSO_2 y 24, 81 t$N0_X$ por año

Cápito 5. Apendice:

Cada uno de los accesorios y componentes usados en la instalción fotovoltaica deben respetar las prescripciones contenida en la normativa de referencia expuesta en este capítulo, donde se incluyen las posibles variaciones, actualizaciones y ampliaciones posteriormente emanadas por sus respectivos organismos.

Por lo que se encuentra recogidas todas las leyes y decretos, normativas técnicas y de seguridad, y deliberaciones correctamente organizadas según orden y fecha.

TOTAL INDEX

CHAP I

STUDY CASE

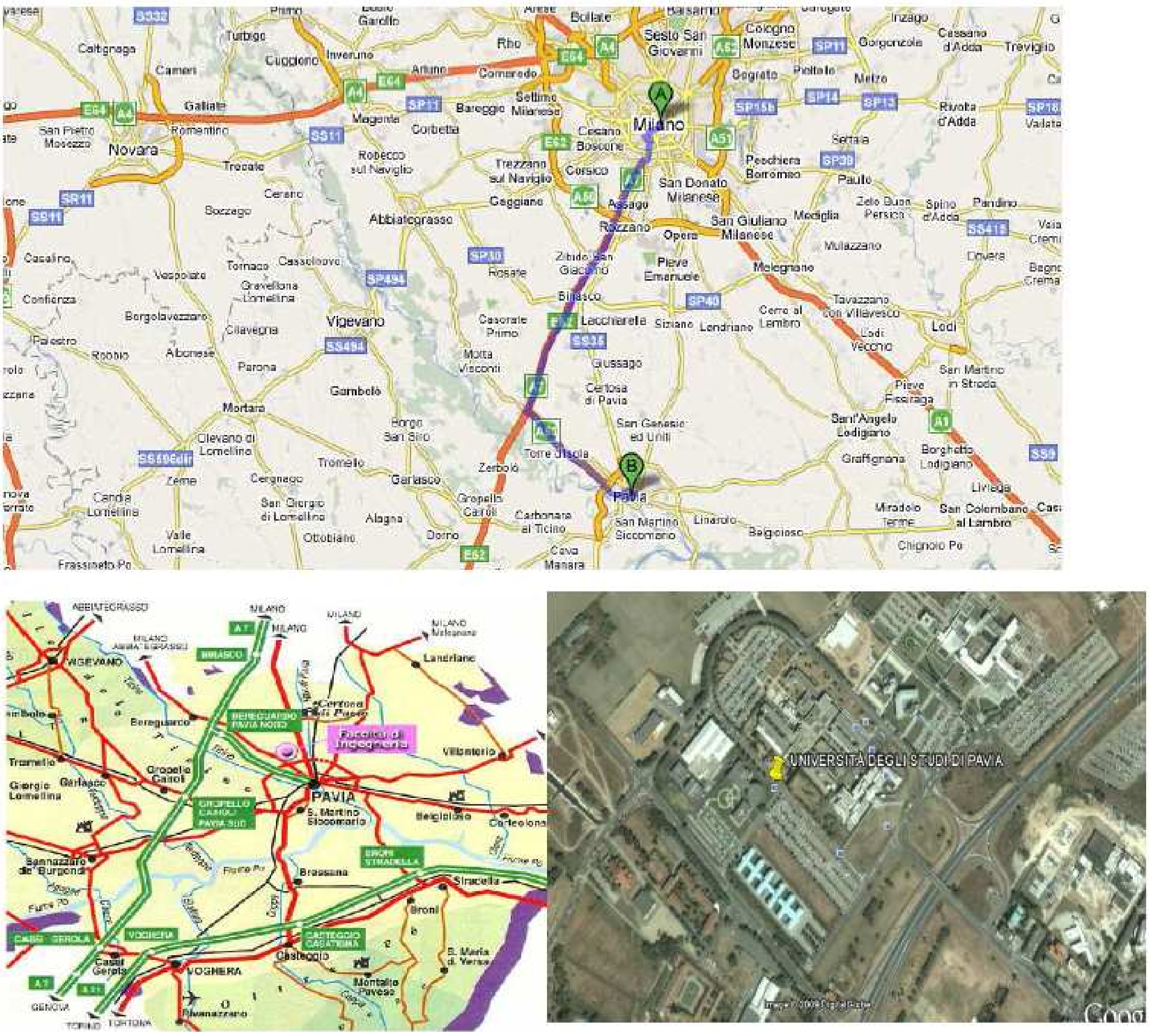
CHAP I: STUDY CASE

1. STUDY CASE

1.1. LOCATION

The PV system described in this project has been installed on the roof completely horizontal of the scientific universtity “Universita degli Studi di Pavia" concretely in the building: "Polo Cravino”, located in an apartment in the suburbs to Pavia´s northwest. The geographic location of the building located on the outskirts, almost in contact with the campaign. Pavia, is a small town a 30 km to Milan:

· Latitude 45°11'36" North
· Longitude: 9°9'21" East
· Altitude: 80 meters above sea level

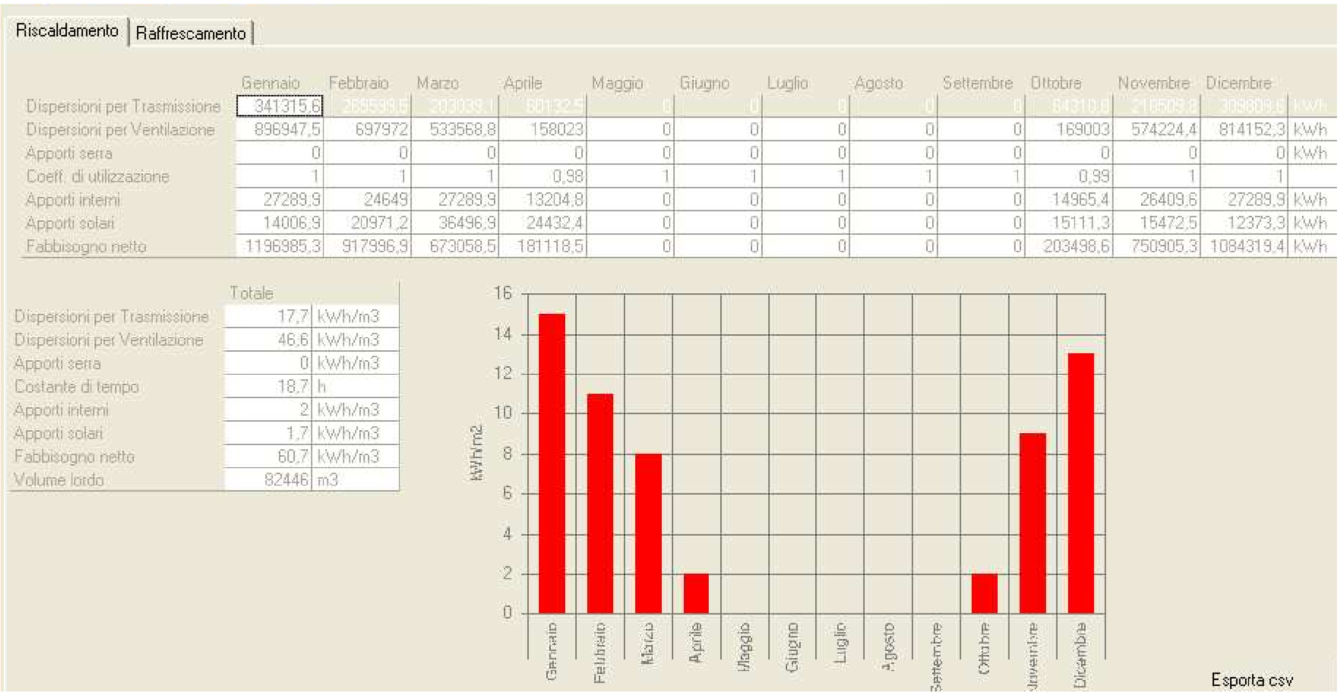


Location “Università degli studi di Pavia” : Sede di Pavia - via Ferrata 1, 27100 Pavia

The size of the photovoltaic and its power rool should be chosen relation to user needs, according to the same power consumption of users , the conditions of Solar radiation at place of installation of the plant and in our proyect isn´t is a problem the surface area available to the PV finally the only constraint to the size of is the financial planned by the owners of the property. .

Because the photovoltaic system will be installed on the coverage level of the university and will be connected to the network public of the local distributor of electricity near the point of delivery. Therefore we have chosen an installation of about 39,6 kWp. From an analysis of historical power consumption of the university you can estimate the average annual consumption of Electricity active of approximately:

Specific energetic Class	E	
Demand of primary energy (winter air conditioning)	E_{PH}	40,3 KWh/m ^{3}
Specific Demand of the wrapper, (winter air conditioning)	E_H	34,1 KWh/m^3
Specific Demand of the wrapper, (summer air conditioning)	E_C	0,8 KWh/m^3
Issues of CO2 equivalent in atmosphere	CO_{2eq}	9,2 Kg/m^3


Riscaldamento | Raffrescamento

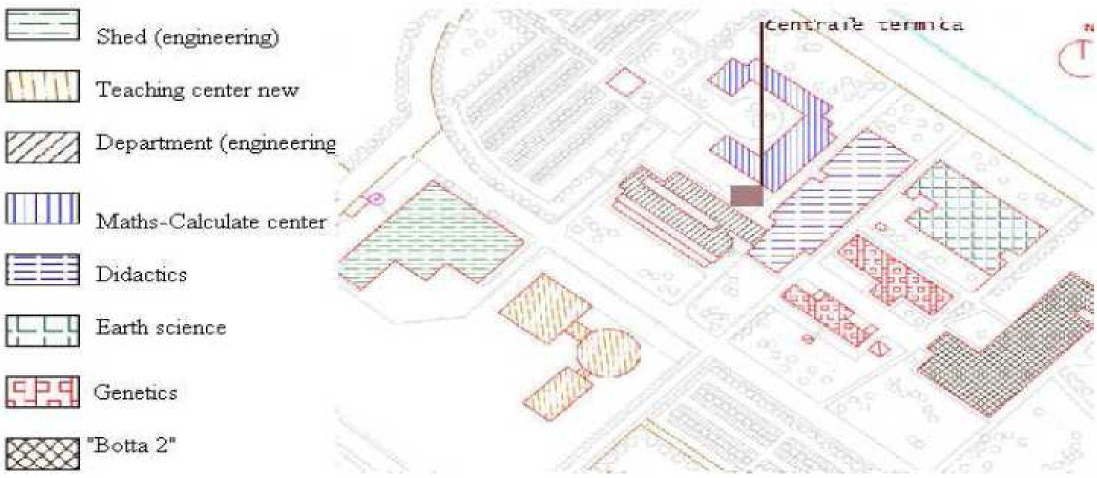
	Gennaio	Febbraio	Marzo	Aprile	Maggio	Giugno	Luglio	Agosto	Settembre	Ottobre	Novembre	Dicembre	
Dispersioni per Trasmissione	341315,6	[illegible]	[illegible]	[illegible]	0	0	0	0	0	[illegible]	[illegible]	[illegible]	KWh
Dispersioni per Ventilazione	896947,5	697972	533568,8	158023	0	0	0	0	0	169003	574224,4	814152,3	KWh
Apporti serra	0	0	0	0	0	0	0	0	0	0	0	0	KWh
Coeff. di utilizzazione	1	1	1	0,98	1	1	1	1	1	0,99	1	1	
Apporti interni	27289,9	24649	27289,9	13204,8	0	0	0	0	0	14965,4	26409,6	27289,9	KWh
Apporti solari	14006,9	20971,2	36496,9	24432,4	0	0	0	0	0	15111,3	15472,5	12373,3	KWh
Fabbisogno netto	1196985,3	917996,9	673058,5	181118,5	0	0	0	0	0	203498,6	750905,3	1084319,4	KWh

	Totale	
Dispersioni per Trasmissione	17,7	kWh/m3
Dispersioni per Ventilazione	46,6	kWh/m3
Apporti serra	0	kWh/m3
Costante di tempo	18,7	h
Apporti interni	2	kWh/m3
Apporti solari	1,7	kWh/m3
Fabbisogno netto	60,7	kWh/m3
Volume lordo	82446	m3

1.2. SYSTEM DESCRIPTION

The constructive solution of the architect Giancarlo De Carlo using a steel frame (to the effects of the certification it is considered to be a structure in armed concrete) with opaque panels in face-toview blocks and sandwich panels. The building has four floors with air conditioned organized one to stagger of the half of a floor between four plans of the front part (B, D, F, H), where there is the entry and the later par of three floors (A , C, E), this solution the ground floor has helped to put a constant socle of double height thath shelters the laboratories and classrooms with some of the major possibilities of the space.
In the next picture we can see the both two wings of the building in the shape of "L" respectively, the spaces for the education and classrooms for workshops and offices.

Sight aeria of the Pole Cravino (wing ingeneering to the left side, and didactic wing to the right).



This installation is part of a project for PV, energetic and biohousing retrieval in a universisty with the objective of reducing the fuel consumption for heating and producing electricity from renewable resources.

1.2.1. CHOICE OF THE BUILDING

The optimal positioning of the PV system would be to the south with an inclination of the modules equal to the latitude of the site. However, the orientation of the university and the geometry of the roof do not allow this target to be achieved, unless using costly and sulky support structures. Therefore, the PV panels have been mounted on the south-east roof of the building with a 30° inclination, which is the best compromise between maximum solar radiation, greatest available surface and minimum costs. The modules are oriented to the south and we have select this roof instead of didactic space, because we can checked in the following photos there are no nearby tall buildings to cast shadows on the PV panels.

The wing of Didactic refused for the installation because the shadows.

The wing of Ingeneering choice for the installation: is oriented longitudinally towards the south-east and northwest. The distribution boss of th planes served by two scale, they repeat themselves almost in its entirety, except in laboratories, where the construction is expanding, and the plane G that to allow roof and gardens, close to the roofe where our photovoltaic installation will place. The interior height of the places in the seven plants is 3.10 m, with the exception of laboratories that have developed a double height and the total height of the building reaches 15.40 m.

PV system has a nominal peak power of 39,6 kWp and is composed of a field installed on the roofs of a wings of the engineering building.

The overall surface availability for the installation is equal to the floor "G": 697 m^2.

COMPLEX BUILDING "POLO CRAVINO"		GROSS SURFACE WARMED (m^2)	NET SURFACE WARMED (m^2)	GROSS VOLUME WARMED (m^3)	NET VOLUME WARMED (m^3)
ENGINEERING WING	FLOOR "A"	1420	1298	5680	4024
	FLOOR "B"	755	672	3322	2083
	FLOOR "C"	1422	1305	6257	4046
	FLOOR "D"	1040	943	4576	2923
	FLOOR "E"	855	768	3762	2381
	FLOOR "F"	845	756	3718	2344
	FLOOR "G"	697	618	3067	1916
	TOTAL	7034	6360	30382	19716

1.2.2. COMPONENTS OF THE INSTALLATION

The components of the plant connected fotovoltaico in parallel to the net are:

· Forms fotovoltaici in silicon polycrystallino.
· Structures of support of the forms fotovoltaici.
· Converter static direct current / alternating current.
· Picture of protection.
· Cables voters and wiring.
· System of mass to earth

The forms will be divided in fields,

The fields are connected in parallel and consist of 240 modules for a total of 15 arrays, each one connected to its own inverter to allow conventional appliances to be powered by PV electricity.

Each array features 16 modules connected in series and is characterized by an open circuit output voltage of 213 V_{DC} and a short circuit output current of 4.4 A.

To provide maximum electrical power output, the angle of the PV array should be changed as a function of the solar altitude, but because of safety and costs the arrays were installed at a fixed angle of 30°.

The modules are made up of polycrystalline silicon, which guarantees a conversion efficiency of about 9%. It´s name is: Mitsubishi:PV-MF165EB4, then shows the modules characteristics at standard conditions (25 °C of ambient temperature and 1000 W/m2 of solar irradiance)

PLACEMENT: The placement of panels in the roof will belong to 5 collectors' lines that we can see the details in the plane .

- First line: The longitude is 67,87 because of this there are 73 panels and on both sites there are a space free of 4 m in order to any manipulation.

- Second and Third line:The longest lines, where there are 81 panels. Also there are on both sites a space free of 4 m.

- Fourth and Fifth: The narrowest line with 4 panels. Are localed in the space near the part of the building where are the stairs, but exactly the further as it´s possible to prevent that it could create possible shades.

Then the modules in the array are wired together in three groups of 80 panels, connected in parallel to each inverter. And each groups of 80 panels also consisting of a 5 subgruops of 16 modules in serie that are among themselves in pararell.

1.2.3. TYPOLOGY OF CONNECTION

The installation will be connected to the net of distribution of the energy electric place according to the regime of pure transfer of the energy. The net will be laced to in formality trifase, to valley of the point of fiscal delivery of the energy, respecting her normative in force of which to the appendix, particularly those related to the dispositions ENEL for the connection of the plant to the public net.

The function of the inverters is to statically convert the electricity from a DC input into an AC output, that means without any rotating devices or mechanical switches. The inverters are connected to the 400 V tree-phase circuit in parallel with the ENEL (national electricity distributor) electrical grid. Therefore, the PV energy output is used directly by the university or fed into the grid depending on the produced power and on the electricity consumption. This allows the electrical power that is not directly consumed to be exchanged. This is particularly important for this kind of building in that during the period of maximum production (summer) there is minimum electrical demand.

PV system main characteristics

Nominal power output:	39,6 kWp
Net occupied surface:	303 m^2
Open circuit tension	213 VDC
Number of arrays:	15
Modules per array:	16

1.3. MEASUREMENT AND CONTROL SYSTEM

The system output is monitored at the PV inverters by a data acquisition system controlled by a Measurement and analysis program (Sunny Boy Control Plus) mounted on a PC. The data acquisition system and the PC communicate with each other by means of a RS232 communication protocol. The data acquisition system features eight digital channels and eight analogical channels. The measured data are:

· electrical power output of each array;
· voltage of each array;
· each phase current fed into the grid;
· each phase electrical power fed to grid.

Also measured and recorded every 15 min are the global solar irradiance on the modules plane in two different locations of the plant, the modules temperatures and the outdoor temperature.

1.4. CONDITIONS FOR THE DESIGN OF INSTALLATION

The amount of solar energy reaching a specific location on the surface of the earth at a specific time depends on two main factors. First the geographical coordinates and in particular the changes in the solar position in the sky with latitude. The sun's position is given in terms of solar altitude and azimuth that can be easily determined. Second are the meteorological conditions with the related climate variations which can be considered as sky conditions.

Name of site = PAVIA

Latitude [°] = 45.183, Longitude [°] = 9.090, Altitude [m] = 77, Climatic zone = III, 3

Radiation model = Default (hour); Temperature model = Default (hour)

Temperature: New period = 1996-2005

Radiation: New period = 1981-2000

RR: Only 4 station(s) for interpolation

Nearest 3 stations: Gh: Milano/Linate (32 km), PIACENZA (IT-AFB) (59 km), Stabio (75 km)

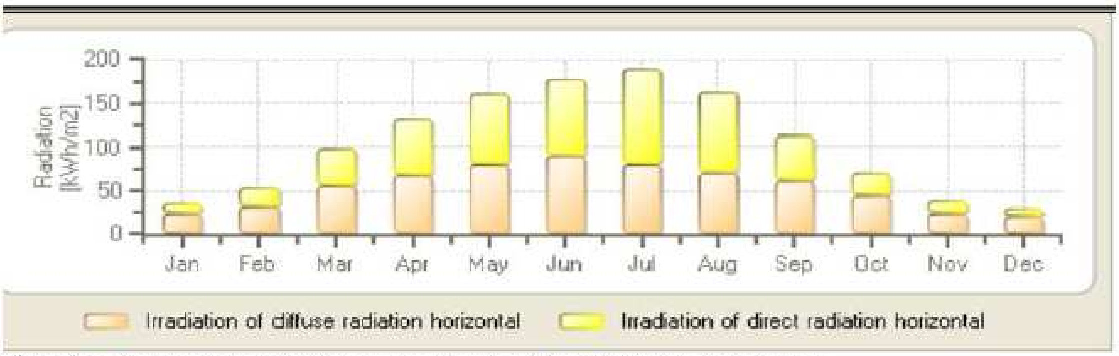
Nearest 3 stations: Ta: Milano/Linate (32 km), CAMERI (IT-AFB) (50 km), PIACENZA (IT-AFB) (59 km)

Month	Ta	Ta min	Ta dmin	Ta dmax	Ta max	RH
	[C]	[C]	[C]	[C]	[C]	[%]
Jan	3.1	-5.4	0.1	6.9	12.6	79
Feb	5.2	-3.5	0.9	10.1	19.4	67
Mar	9.8	-1.5	5.0	15.2	21.9	64
Apr	13.0	3.4	8.2	17.6	24.5	66
May	19.0	8.4	13.9	23.8	31.2	65
Jun	23.2	12.6	17.9	27.6	34.0	64
Jul	24.5	15.2	19.6	29.5	35.0	64
Aug	24.5	14.6	19.9	29.2	35.2	68
Sep	19.5	10.3	14.8	24.1	31.1	70
Oct	14.5	4.8	11.1	18.6	25.5	79
Nov	8.1	-1.2	5.0	11.6	20.7	80
Dec	3.9	-5.0	0.9	7.5	14.7	79
Year	14.0					71

Ta: Air Temperature; (oC)
Ta min: Minimum Ta (oC) **Ta max:** Maximum Ta (oC)
Ta dmin: Mean daily minimum Ta (oC) **Ta dmax:** Mean daily maximum Ta (oC)
RH: Relative humidity (%)

Month	H_Gh	SDm	SDd	SD astr.	RR	RD	FF	DD
	[kWh/m2]	[h]	[h]	[h]	[mm]	[d]	[m/s]	[deg]
Jan	36	65	2.1	9.0	49	6	1.2	192
Feb	54	92	3.3	10.3	62	6	1.6	191
Mar	99	148	4.8	11.7	88	7	1.9	105
Apr	132	174	5.8	13.3	128	7	2.0	80
May	161	208	6.7	14.7	188	8	2.0	118
Jun	177	235	7.8	15.4	102	6	1.9	145
Jul	109	277	0.9	15.1	140	5	1.9	112
Aug	164	245	7.9	13.9	169	6	1.6	125
Sep	114	182	6.1	12.4	153	4	1.5	133
Oct	71	129	4.2	10.8	154	6	1.3	114
Nov	38	70	2.3	9.4	219	7	1.3	194
Dec	29	60	1.9	8.6	89	5	1.2	184
Year	1262	1884	5.2		1541	73	1.6	135

H_Gh: Irradiation of global radiation horizontal (Kwh/m2);
SDm: Mean daily Sunshine duration (h);
SDd: Sunshine duration (h);
SD astr: sunshine duration astronomic (h);
RR: Precipitation (mm)
RD: Days with precipitation (d)
FF: Wind Speed (m/s)
DD: Wind Direction (deg)



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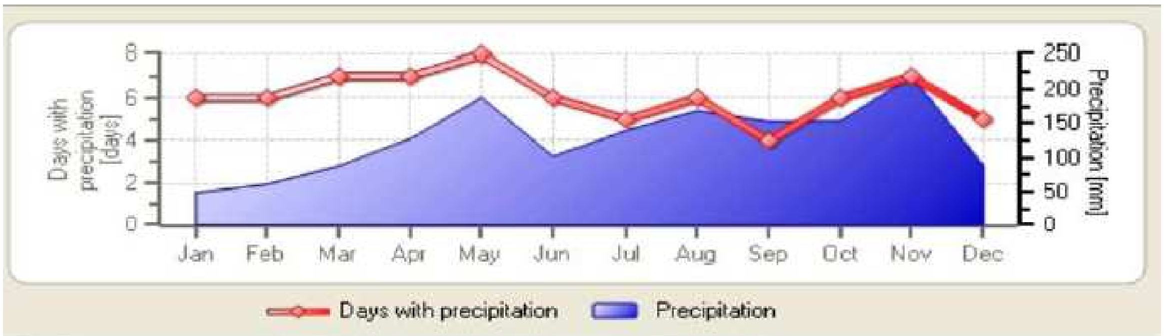

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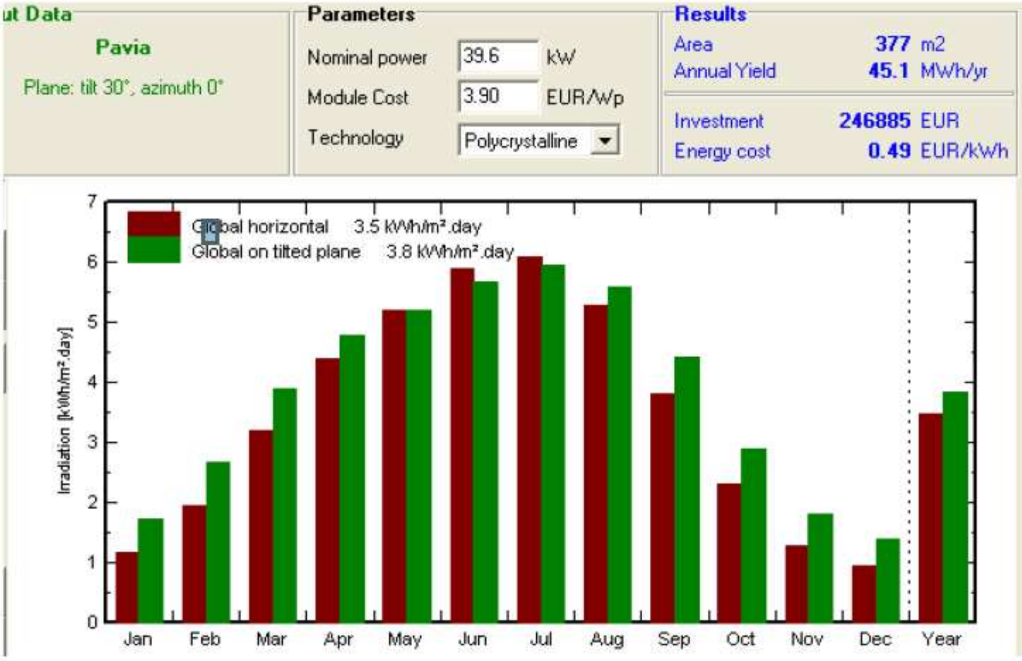
1.5. IRRADIATION

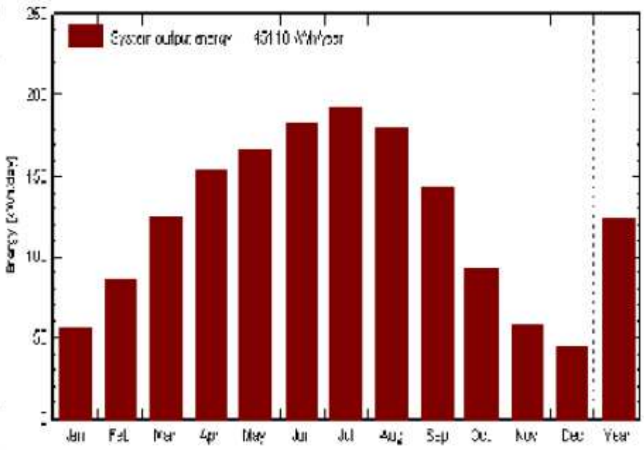
The intensity of the direct daily solar radiation received by the system has been calculated knowing the system inclination and orientation and the geographic coordinates of Pavia.

Under clear sky conditions, the system would receive about 3.5 kWh/m^2 of day solar global horizontal irradiance against 3.8 kWh/m^2 that would be received in the optimal orientation, on tited plane. This are the results obtained with our software PVSYST choosing the first option: Preliminary.

Design and knowing that our study case is Grid connected, with a nominal power of 39,6 Kw (calculated down), and with the specification of Standard Polycrytalline cells, mounting disposition on the flat roof, and ventilation property: free standing.



	Gl. horiz. kWh/m².day	Coll. Plane kWh/m².day	System output kWh/day
Jan.	1.16	1.72	55.57
Feb.	1.93	2.67	85.96
Mar.	3.19	3.88	125.2
Apr.	4.40	4.78	154.2
May	5.19	5.18	167.0
June	5.90	5.66	182.6
July	6.10	5.96	192.0
Aug.	5.29	5.59	180.1
Sep.	3.80	4.42	142.4
Oct.	2.29	2.89	93.21
Nov.	1.27	1.81	58.22
Dec.	0.94	1.38	44.40
Year	3.46	3.83	123.6

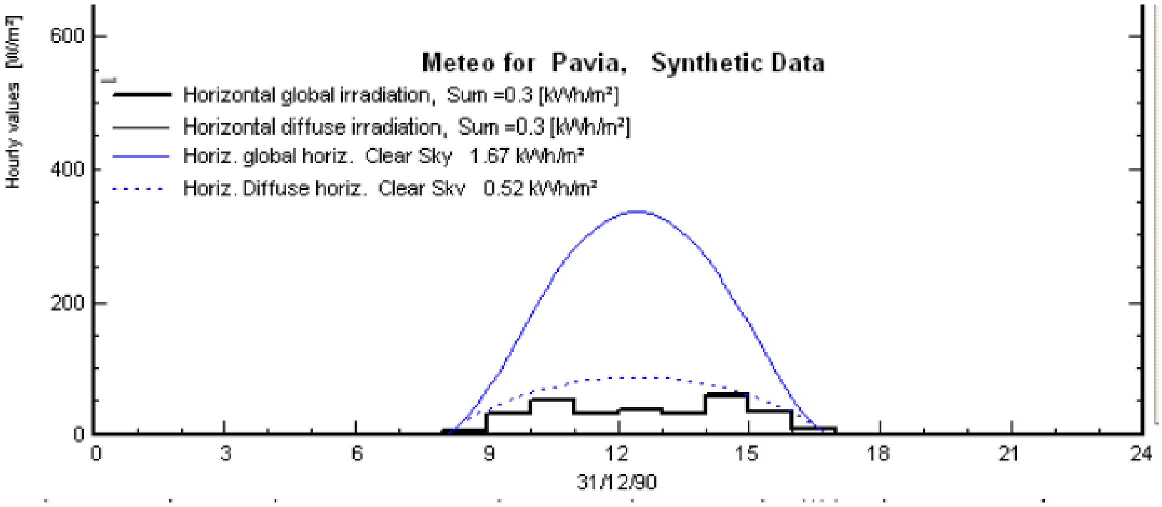


1.5.1. CLEAR SKY RADIATION

The comparison between optimal and actual orientation in terms of clear sky incident solar irradiance during a year is shown in next figure of PVSYST.

Clear sky radiation is an ideal condition that can be calculated in a deterministic manner since it depends only upon sun–earth relative motion. On the other hand,

To be noted: a "clear day" may be superimposed on the daily curves, allowing for checking the data timing quality.



1.5.2. OPTIMAL ANGLE

PV modules produce most power when they are pointed directly at the sun. It is important to install them so that they receive maximum sunlight. Ideally they should be in full sun from 9am to 3pm in mid winter.

The chart below for latitude 30° shows the effect of orientation and elevation on module output, expressed as a percentage of the maximum possible output. And with the Software Solarius-PV we can corroborate that with this tilt we obtain the better “rendimento”:Output.

Azimut	Tilt	Irradiazione annua	Rendimento
0	30	1 435.67	100.00
4	31	1 435.36	99.98
-4	31	1 435.36	99.98
5	30	1 435.36	99.98
1	30	1 435.36	99.98
-1	30	1 435.36	99.98
-5	30	1 435.36	99.98
6	29	1 435.36	99.98
3	29	1 435.36	99.98
-3	29	1 435.36	99.98
-6	29	1 435.36	99.98
5	28	1 435.36	99.98
4	28	1 435.36	99.98
-4	28	1 435.36	99.98
-5	28	1 435.36	99.98

1.6. INTEGRATION OF PV IN ARCHITECTURE

There are currently various types of PV modules that generate electricity from sunlight. The modules that were originally installed on roofs, structures or land had a standard structure for most of their uses. However, in recent years the fields of design and architecture have started using PV modules in construction, thereby integrating them as an additional design material.

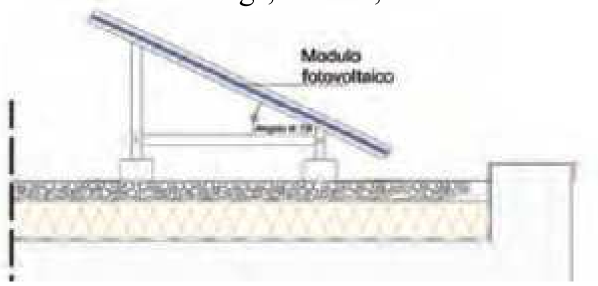
The surface of a well-oriented facade is the ideal location of a PV installation, which will provide a building with financial, aesthetic, energy and environmental benefits. Therefore, to minimise their visual impact and to truly convert these modules into a construction material, technology has evolved and now allows modules to be designed and produced in order to provide architectural integration that brings together energy production and building sustainability using modern, ecological and avant-garde aesthetics.

Architectural integration consists of combining the classic function of PV modules as electricity producers with the function of an integrated construction element. it is essential that, in it insertion the PV not invalidated the aesthetical characteristics and the functionality of the architectural wrap, kind for what concerns the energetic efficiency of the building.

This typology includes the plain roofs and the terraces. With reference to the norm UNI 8627 "Systems of coverage”. Definition and classification, plain roof the horizontal coverages and suborizzontali are considered with inclination of the element of estate up to 5% (around 3°).

Plain roofs and terraces can foresee elements perimetrali as mouldings, cordoli, balusters or handrails.

To the purpose of the recognition of the partial integration in presence of high perimeter elements up to 50 cm from earth, the plant can be climbed on without limitations of height of the support of the forms.



1.6.1. STUDY OF SHADES

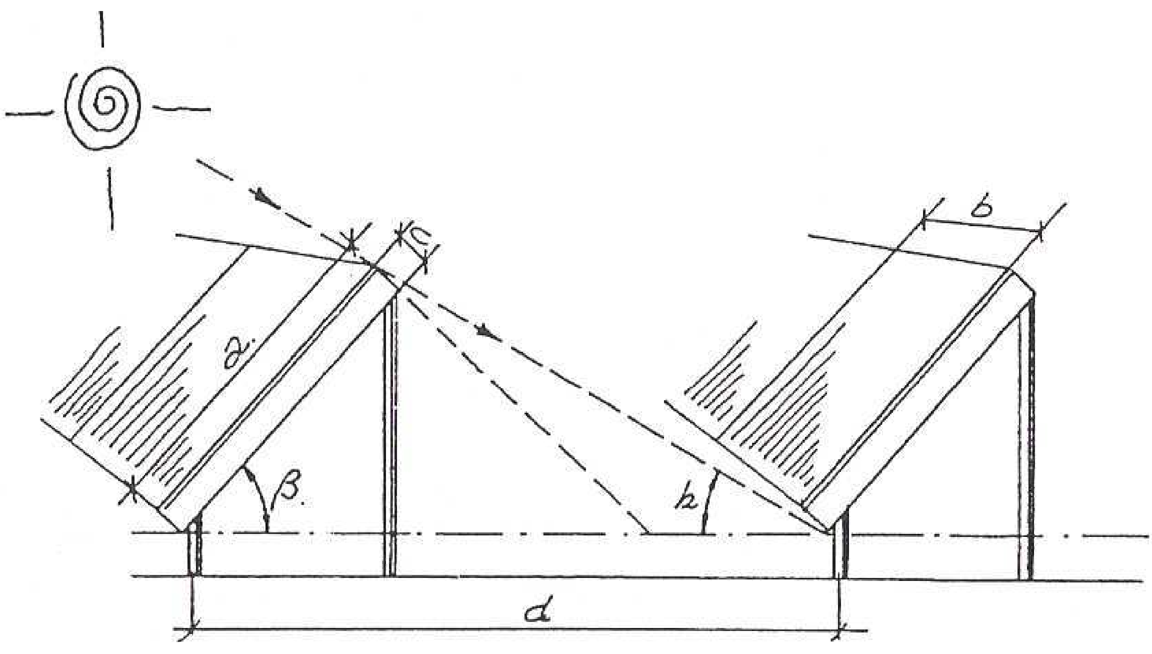
Shadows cast by tall trees and neighbouring buildings must also be considered. Even minor shading can result in significant loss of energy. Because it, in order to minimize the effect of shade on the amount of electricity produced, we have select a flat without shadows near. The above mentioned question presents two fundamental points with the indispensable requirement that does not project any shade on the following plate in the midday of the winter solstice.

1) Minimal acceptable separation between (among) collectors' consecutive batteries:

In the installation they are observed as consecutive and parallel batteries in which the shade projected by the first one comes at the foot of the second one. Of the formed triangle we can obtain the separation between collectors of 3,38 m.

Like *ß* and *a* are fixed, the distance between collectors depends only on the solar height(hc)

This way, from the different values that it takes h for a given latitude of 45,185 o, we can find the values between which the distance is included between collectors.



Where:

s, the angle of inclination of the panel that we keep fixed and with a value of **30º**.

hc, the solar height of the winter solstice. **hC = 90º – (Latitude – Slope)= 90º- (L - δ)**

90º –(45,185 + 23,45) = 21,365

$$\delta = 23{,}45 \cdot sen\left(360 \cdot \frac{284+N}{365{,}25}\right) = \delta = 23{,}45 \cdot sen\left(360 \cdot \frac{284+355}{365{,}25}\right) = \mathbf{-23{,}4498}$$

N=355	δ=-23,449878	**21-dec**

d, distance between collectors measured from the foot of the collectors' first battery at the foot of the second one.

a, the height of our panel.

Distance between collectors to avoid the projection of shade:

$$d = (a)\cdot\cos(\beta) + \frac{a\cdot sen(\beta)}{tag(h)} = 1.580\cdot\cos(30°) + \frac{1.580\cdot \mathrm{sen}(30°)}{\mathrm{tag}(21{,}365°)} = 3387{,}79$$

2) Shades projected throughout the year, for obstacles, on the collectors.

For the calculation of the not useful area, we must identify the height (hobstacle) of the obstacle in our project the shades projected because the building where there is the stairwell, and apply the following formula, knowing that k is a value depending on the latitude:

$$d = \frac{h_{obstacle}}{tg(67°-latitud)} = \frac{h}{k} = \frac{8}{2.475} = 3{,}23$$

Latitude	29	37	39	41	43	45
k	1,280	1,732	1,881	2,050	2,246	2,475

1.6.2. ALBEDO FATOR

The albedo coefficient is the fraction of global incident irradiation reflected by the ground in front of a tilted plane.

This effect takes place during the transposition computation of the horizontal irradiation onto a tilted plane. The albedo "seen" by the plane is of course null for an horizontal plane, and increases with tilt.

In the project definition, the albedo values can be adjusted each month in order to take any possible snow-cover into consideration. The value usually admitted in the urban localities is of the order of 0.14 to 0.25, and can go up till 0.8 for a snow-cover. Ideally, the best value is obtained by a direct measurement on the site. But in practice, except for vertical planes, this value does not take on any great importance as the albedo component is relatively weak in the incident global irradiation (this contribution can be visualised in the results of your simulation).

Also it can by the formula:

A= $G_{or} \cdot \rho_{g.} \cdot (1-\cos\beta/2)$; **G_{or}** = radiation on the horizontal plane
$\rho_{g.}$ = albedo factor
β= optimal angle

But in our case is obtained with Solarius-PV and the following table gives some usual values for the albedo:

Albedo medio annuo 0.25

Attiva ☑	Gen	Feb	Mar	Apr	Mag	Giu	Lug	Ago	Set	Ott	Nov	Dic
Albedo medio mensile	0.40	0.30	0.23	0.20	0.20	0.20	0.20	0.20	0.23	0.23	0.30	0.35

Valori di albedo presenti nella norma UNI 8477

Valori di albedo presenti nella norma UNI 8477

Neve (caduta di fresco o con film di ghiaccio)	0.75
Superfici acquose	0.07
Suolo (creta, marne)	0.14
Strade sterrate	0.04
Bosco di conifere di inverno	0.07
Bosco in autunno/campi con raccolti maturi e piante	0.26
Asfalto invecchiato	0.10
Calcestruzzo invecchiato	0.22
Foglie morte	0.30
Erba secca	0.20
Erba verde	0.26
Tetti o terrazze in bitume	0.13
Pietrisco	0.20
Superfici scure di edifici (mattoni scuri, vernici scure, ...)	0.27
Superfici chiare di edifici (mattoni chiari, vernici chiare, ...)	0.60

1.7. STRUCTURES OF SUPPORT

For the laying of the PV module must be handled the installation of a structure of support. The structure has both the function of support of the module is the function to get the optimal inclination of the forms (30° in comparison to the horizontal one).

The structure must be composed from easels in galvanized steel or in steel inox and from current on which will settle the forms fotovoltaici through "zeta" and "omega" also them in galvanized steel or inox. The waterproofing of the coverage of the university building is gotten through scabbards termosaldate. It is not possible therefore to fix the structure of support to the insole of the coverage of the building through of the wedges of anchorage without perforating the scabbards and therefore to jeopardize the waterproofing. The easels of the structure must have fixed therefore to ballasts supported to the same coverage. It ballasts can be constituted by riddle in cement of suitable weight. Among it ballasts and the coverage recommends him to interpose a sheet of PVC not to damage the scabbards termosaldate.

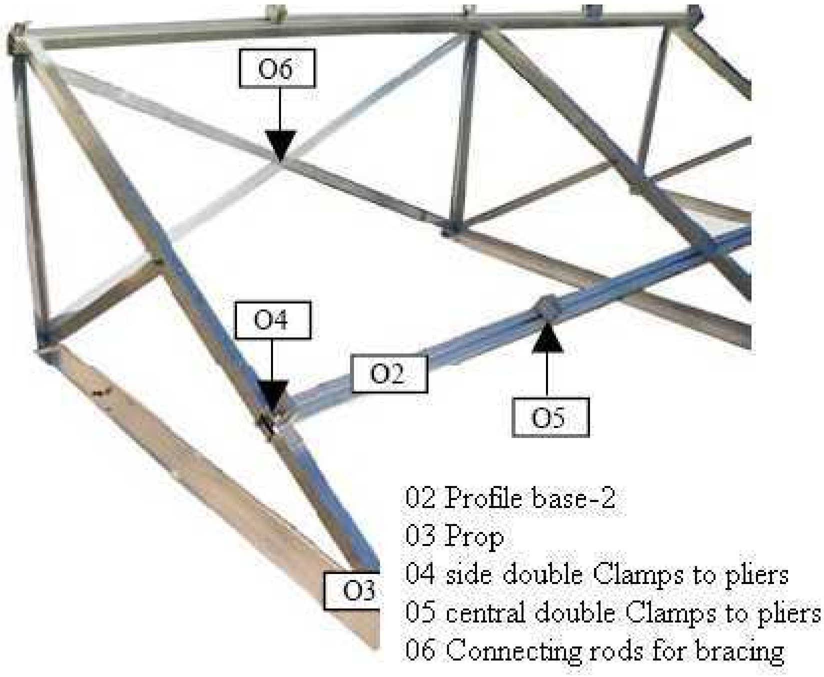
• *Weight:* The pre-fabricated concrete foundations weigh 90 kg.

• *Fixing possibilities:* The aluminium sections that support the PV panels are bolted to the concrete foundation to form a triangle. The PV panels are fixed to the aluminium using either adhesive tape or screws, depending on whether a laminate or framed panel is chosen.

• *Visual details:* The PV modules are the most dominant feature of this system. The concrete foundation and aluminium frames are a light grey colour.

The PV plant will be installed to earth through metallic structures in aluminum, it brand HELIOS TECHNOLGY S.r.l. That are the caractheristic of : Simple and rapid assemblage (2 grapevines), inclination PV module equal to 30°, available 7 holes for the fixing of the profiles, and anchorage of the ground, with the possibility to fix through wedges or ballast.

The form of the profile of support excellently reflects the static and dynamic loads.



1.7.1. LOADS AGENTS ON THE STRUCTURES

The array mounts will support the modules and will also provide mounted under the array so typical high-pole, parking lot fixtures will not cause shading on the modules. In designing the array mounting system, it is first necessary to compute the mechanical forces acting on the array. These forces will then be transmitted to the array support structure and are determined because the location. The types of loads need to be considered are:

· **Weight of the array and support structure really**
· **Snow**
· **Wind**

Other loads what the shock and the temperature are neglected because less serious and can´t be accumulated with the considered (wind and snow) loads or because they don't behave meaningful states of strain (structures isostatic). The snow loads and from wind they are combined according to what anticipated from the normative in force for the calculation of the solicitations agents on the structures.

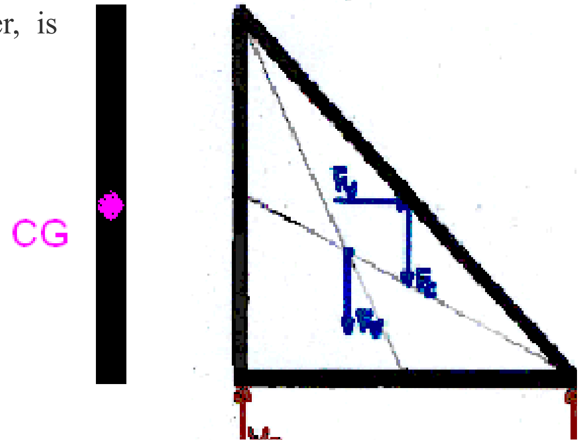
1.7.2. STATIC TESTED, CERTIFIED AND SIGNED

One of the most important aspects to consider in the development of photovoltaic systems is static. The use of materials improper or incorrectly sized components can cause problems of resistance to snow loads damaging system and, in extreme cases, causing a dangerous situation. To rule out such occurrences, for each editing system, the smallest piece sliding up to the supports and clamps modules, Schuco controls not only the quality and properties
static individual components, but also their interactions within the group constructively. This process is executed in accordance with the rules of relevance and based on preliminary data such as snow loading.
The certificates are fully available for the customer to double check the quality standards of all system components and the system as a whole.

- **Certificate of static according to DIN 1055**
- **DIN 4113**
- **DIN 18800**

1.7.3. STUDY OF THE FORCE OF THE MODULE

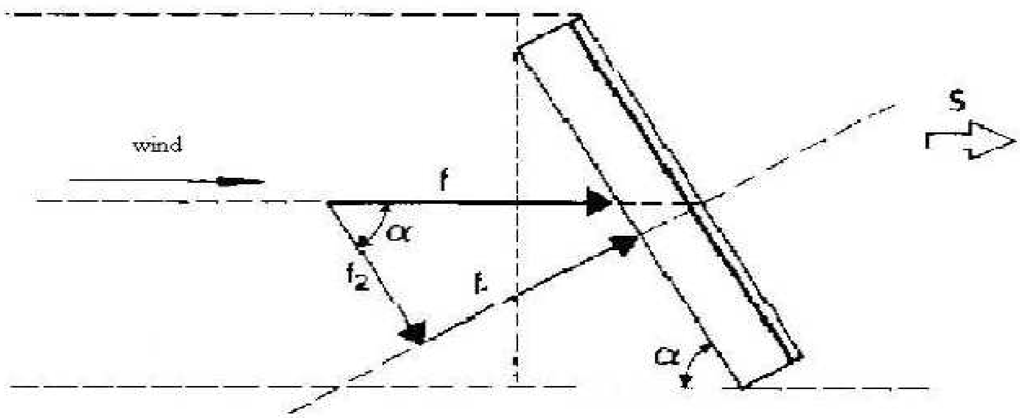
The weight of the module given by the manufacturer, is of 16 kg, that is 156.8 N. The effort of each support is 39,2 N.
The next figure shows the resultant forces, and their vertical and horizontal component:.
Fv: Force of the wind
Fc: Weigh of the panel
Fe: Weigh of the struture
Va, Vb: **Vertical reaction of each support**
H: Horizontal Reaciotion of each support



1.7.4. STUDY OF THE FORCE OF WIND AND INCLEMENT WEATHER DEBRIS

In this case if necessary to perform the calculations necessary to study which type of fastener is the most suitable to withstand the stress caused by the force of wind and inclement weather debris.

As the photovoltaic modules will be oriented to the south, the only wind that can represerntar risk is coming from the North, because that place is the tensile forces on the anchors, which are more dangerous than the compression.



To find the forces that will act on the modules, we will rely on the following expression:

$$F = p \cdot S \cdot sen\alpha$$

Where S: surface of the panel (m)

α :panel tilt angle (º)

P: Frontal wind pressure (N / m)

$$f1 = f \cdot \sin\alpha = p \cdot S \cdot \sin\alpha \cdot \sin\alpha = p \cdot S \cdot \sin^2\alpha$$

The wind force f perpendicular to the vertical surface, decomposes in f1, which acts perpendicular to the surface of the collector and is the most important. f2 which is parallel and causes the sliding of the air, the effects of which cause friction and eddies along the entire surface of the module

3. *Hypothesis:*

v [m/s]	v [km/h]	p [N/m^2]	p [kp/m^2]
30	108	550	56.1

4. *Data obtained :*

f_1 [N]	f_1 [kp]	Momento de vuelco
173.8	17.73	12,13kp·m

5. ***Slab Foundations****:* Once known the value of f1, we want to make a concrete base capable of supporting and counter this force, this will compare both tilting moments and must meet the concrete base is more than the wind.

high [m]	width [m]	Leghth [m]	Density concrete [kp·m^3]	Weight [kp]	Momentum [kp·m]
0.2	0.2	1	2200	72	36

1.7.5. HOW TO SIZE AND CHOOSE THE ELEMENTS OF A STRUCTURE ROOF PLAN

The formula used to determine the required length of the profiles is as follows:
Ltot [mm] = total length of profiles = 22mm + [nº of modules · (Length panel +21 mm)]

Determine the total length of the profiles you are able to trace the necessary amount of profiles, depending on the load static and the length of the single rod used (2866mm or 6150mm) as outlined in paragraphs 1.3.2 and 1.3.3.

Calculation of lateral and central terminals for attachment of the PV modules profile:

- *Terminals Lateral Side Clamp aluminum*, complete with stainless steel screws and counterplates.
For each row of PV modules are needed = 4 pieces
- *Clamp double central aluminum*, complete with stainless steel screws and counterplates.
For each row of PV modules are necessary pieces = 2·(number of solar modules -1)

Figura 1

Figura 2

Line 1: nº modules = 10 · 7 + 3 = 73

nº row : 10 + 1 = 11

nº Terminal lateral sice clamp aluminun= 4 · 11 =44

nº Clamps double central aluminum = 10 · [2·(7-1)] + [2 · (3-1)]= 124

Line 2: nº modules = 11· 7 + 4 = 81

nº row : 11 + 1 = 12

nº Terminal lateral sice clamp aluminun= 4 · 12 = 48

nº Clamps double central aluminum = 11 · [2·(7-1)] + [2 · (4-1)] = 138

Line 3 : nº modules = 11· 7 + 4 = 81

nº row : 11 + 1 = 12

nº Terminal lateral sice clamp aluminun= 4 · 12 = 48

nº Clamps double central aluminum = 11 · [2·(7-1)] + [2 · (4-1)] = 138

Line 4: nº modules = 5

nº row : 1

nº Terminal lateral sice clamp aluminun= 4 · 1 = 4

nº Clamps double central aluminum = 1 · [2·(4-1)] = 6

TOTAL = nº Terminal lateral sice clamp aluminun = 144

nº Clamps double central aluminum = 406

1.7.6. DETERMINE THE TOTAL NUMBER OF PROPS, PROFILES AND RODS

- *Bracing rods*
  The bracing rods complete with 4 fixing screws must be fitted with pins spaced at 1500mm exploiting holes present, as shown in figure:

Figura 5

Line 1*:* 10 row of 7 module: Ltotal= 22 mm + [7 · (800 + 21)mm]= 5,769m

1 row of 3 module: Ltotal = 22 mm + [3 · (800 + 21)mm]= 2,485

Quantity profiles aligned :10 · 2 + 1 = 21

Number rods : 10 · 2 + 1 = 21

Set junction: 10 couple + 1

Line 2 : 11 row of 7 module: Ltotal= 22 mm + [7 · (800 + 21)mm]= 5,769 m

1 row of 4 module: Ltotal = 22 mm + [4·(800+21)] = 3,306 m

Quantity profiles aligned :11 · 2 + 2 · 2 = 26

Number rods : 11· 2 + 2 · 2= 26

Set junction: 11 couple + 1

Line 3: 11 row of 7 module: Ltotal = 22 mm + [7· (800 + 21)mm]= 5,769 m

1 row of 4 module: Ltotal = 22 mm + [4·(800+21)] = 3,306 m

Quantity profiles aligned :11 · 2 + 2 · 2 = 26

Number rods : 11· 2 + 2 · 2= 26

Set junction: 11 couple + 1

Line 4: 1 row of 5 module: Ltotal= 22 mm + [5· (800 + 21)mm]= 4,128 m

Quantity profiles aligned : 2 · 2 = 4

Number rods : 2 · 2= 4

Set junction: 1 couple

TOTAL: Quantity profiles base-2 in all. length equal to 2, 866 m.= 76

Blacing rods complete with fasteners for the system : 152

Set junction : 35 couple

1.8. CHOICE THE ELEMENTS OF PHOTOVOLTAIC

The installation, classified as "not integrated", it is type grid-connected and the formality of connection it is in "Three-phase in average voltage"

The power is equal to 39.60 kWs, and the production esteemed of 42 700.68 kWhs of annual energy, it derives from 240 occupying forms a surface of 303.36 m^2. And is divided in 3 generators, classified as "Generating not integrated", it has power equal to 13.20 kWs and a production estremed of 14 233.56 kWhs of annual energy, consequential from 80 occupying forms a surface of 101.12 m^2s.

As it regulates general we can try to maintain the voltage of the series of panels higher possible, up to reach the maximum limit dell inverter.

In this way you will reduce the tide of the lace principal source of losses. As it regards the number of the strings in parallel, it only depends from that power has the inverter.

Because more strings in parallel entails to get more power.

1.8.1. GENERATOR

Once let's know the distances between panels, we will see which is the maximum of them that they will fit in the surface which we have. In our case they have been 240 modules.

With the total number of panels we will be able to find the total power according to which we will choose the suitable investor:

$$P_{\max.total} = P_{\max,nom} * N_{pt} = 165 * 240 = 39{,}60 \approx 40kWp$$

The power of the investor will be similar to 80 % of the maximum total power:

$$P_{inversor} = P_{\max,total} * 0.8 = 40*0{,}8 = 24{,}192 \text{ Kwp} = * 0.8 = 31{,}68 \text{ Kwp}$$

18.2. ARRANGEMENT OF PARALLEL AND SERIES PANELS

The open circuit voltage (Voc) is 30,4 V, but this voltage can vary with temperature,

The coefficient of temperature is given by the manufacter: **- (102) mV / K**

The variation in temperature is 40 K (30 ° C-10 o C), thus increasing the voltage at 4.08 V is the maximum voltage of 34.06V.

Because the maximum voltage of the inverter is 400 V, batteries should be placed in series of 18 modules.

But in order to make the simple circuit and more symmetrical, and according to the PVSYST we have decided that the number of panels are 16 series, and 15 modules in parallel and connected to the three inverter.

1.8.3. TYPOLOGY OF THE INVERTOR

With regard to the investors' placement, were studied diferenes alternatives depending on the number of investors and on the way connecting them.

We eliminate the possibility of using an only one invertor, because it´s very risky, since in case of breakdown the serious totally unproductive installation, and it should do a meticulous and costil maintenance of the investor to minimize the possibilities of failure.

We reject also a high number of investors, since it involves a cost in the investment and unnecessary maintenance.

Finally the chosen configuration corresponds to 3 investors SUNWAY TG-14 600V because it minimizes the risks and the expenses. In addition with this configuration the tasks of maintenance are facilitated on having had the installation organized in tree equal sectors being able to disconnect each of these sectors separately. These investors will place in the center, minimizing this way the necessary number of protection sheds being able to integrate 3 investors and the central box of connection under the same construction that will be protected from possible exterior assaults on having placed removed from the perimeter of the plot.

18. 4. GUARD AND CONTROL PANEL

The devices of protection are fundamental for:

· to protect the components of the installation from possible anomalies of operation owed to overloads of voltage or tide;
· to isolate the installation in the case works of maintenance is developed to the plant or to the net of distribution.

Particularly, the protections used for the plant in object are the followings:

- *Side direct current: I*n the part of plant characterized by direct current the positioning it foresees him of:

· Spark gap that allows the safety dissection of the PV field;
· Fit diodes to guarantee the correct circulation of the tide in the laces;
· Unloader of protection overvoltage of the inverter.

- *Side alternating current:* In the part of plant characterized by alternating current the positioning it foresees him of:

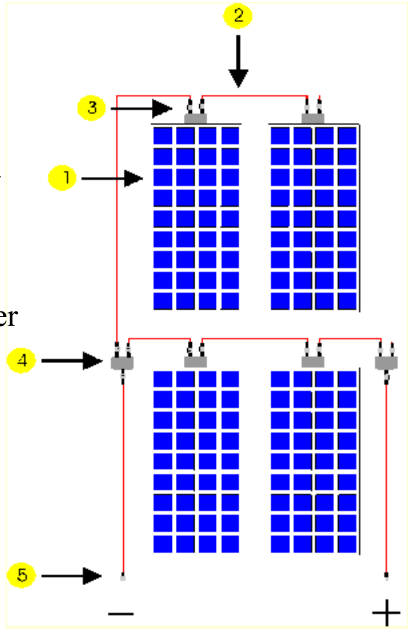
· Spark gap differential magnetic-thermal downstream of the inverter (device of generator);
· Unloader of overvoltage and spark gap magnetic-thermical downstream of the counter of measurement of the energy produced by the installation.

All the select devices are in operation dimensionati of the power of the PV field and in the respect of the normative in force.

1.8.5. CONNECTORS AND WIRES/CABLES IN PV SYSTEMS

The main difference between AC electrical and low voltage DC photovoltaic system installation is different voltage range at PV systems and much higher currents. The system's careful design should consider proper wire sizing allowing for efficient operation. The most important parameter is the wire section. Inappropriate wire sizing could result in excessive heating and even fire due to large current. Properly connected and sized wiring won't require any maintenance for years. Exterior modules and other PV components connection wires and cables should be used with UV radiation resistible insulation. The main difference between AC electrical and low voltage DC photovoltaic system installation is different voltage range at PV systems and much higher currents. The system's careful design should consider proper wire sizing allowing for efficient operation. The most important parameter is the wire section. Inappropriate wire sizing could result in excessive heating and even fire due to large current. Properly connected and sized wiring won't require any maintenance for years. Exterior modules and other PV components connection wires and cables should be used with UV radiation resistible insulation. Standard wire and cable insulation cracks under years of exposure to atmospheric conditions and UV radiation. The temperature range is also important.

Exterior cables should allow for temperature range from -45°C to up to +80°C or even more. Application of such cables will enable efficient system operation for the next two decades or longer. Standard, usually stranded wires a nd cables are used for interior connections.



CONNECTORS: The most common connector types used in PV are "MC", Tyco "Solarlok" and Huber+Suhner connectors. Suitable tools for assembly is needed. Basic wiring parts are presented on the pictures below. Picture below left: junction box (3), connector (5), T-type connector (4), wire (2). Wiring example for two paralel strings with 2 modules in each string is presented.

1.8.6. THE TECHNICAL-FUNCTIONAL CHECK

The technical - functional check of the installation consists of quarrelling:

- the electrical continuity and the connections between(among) modules;
- The capture to land of masses and unloaders;
- The isolation of the electrical circuits of the masses;
- The correct functioning of the photovoltaic installation in many conditions of generated power and in several modalities foreseen by the flushed group of conversion
- The condition: $\mathbf{P_{cc} > 0,85\ P_{nom} \cdot I / I_{STC}}$,

Where:

- P_{cc} is the power, in kW, restrained to the exit of the photovoltaic generator, accurately better of 2 %,

- P_{nom} is the nominal power, in kW, of the photovoltaic generator;

- I it is the radiation, in W/m^2, restrained on the plan of the modules, accurately better of 3 %, (class 1 °);

- I_{STC}, equal to 1000 W/m^2, is the radiation in standard conditions;

The condition: **P_{ca}> 0,9· P_{cc}**, where: P_{ca} is the active power, in kW, restrained to the exit of the group of conversion, with accurately better of 2%

·The condition: Pca > 0,75 Pnom I / ISTC.

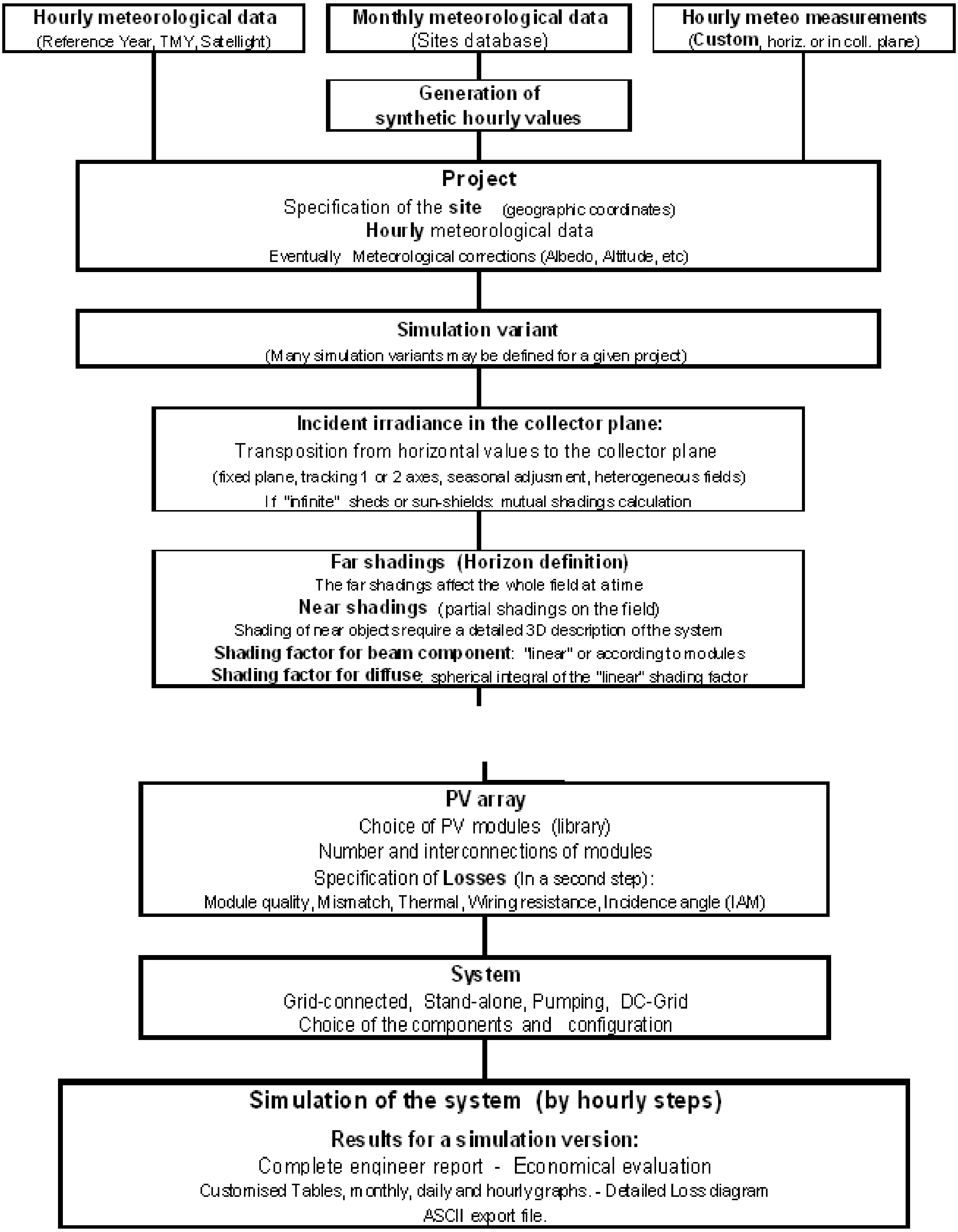
1.9. COMPARATION WITH SOFTWARE

And according to the Simulation of PVSYST which aim is perform a PV-system design and nalysis using detailed hourly simulations.

These are organised in the framework of a Project, which essentially holds the geographical situation and meteorological hourly data. Optimisations and parameter analysis can be performed through different simulation runs, called variants.

After simulation, each variant may be saved for further comparisons (please use "Save as" for not overwriting your previous variants). You are advised to define a significant description for each variant, in order to easily retrieve them in the list and to obtain a suited title in your final report.

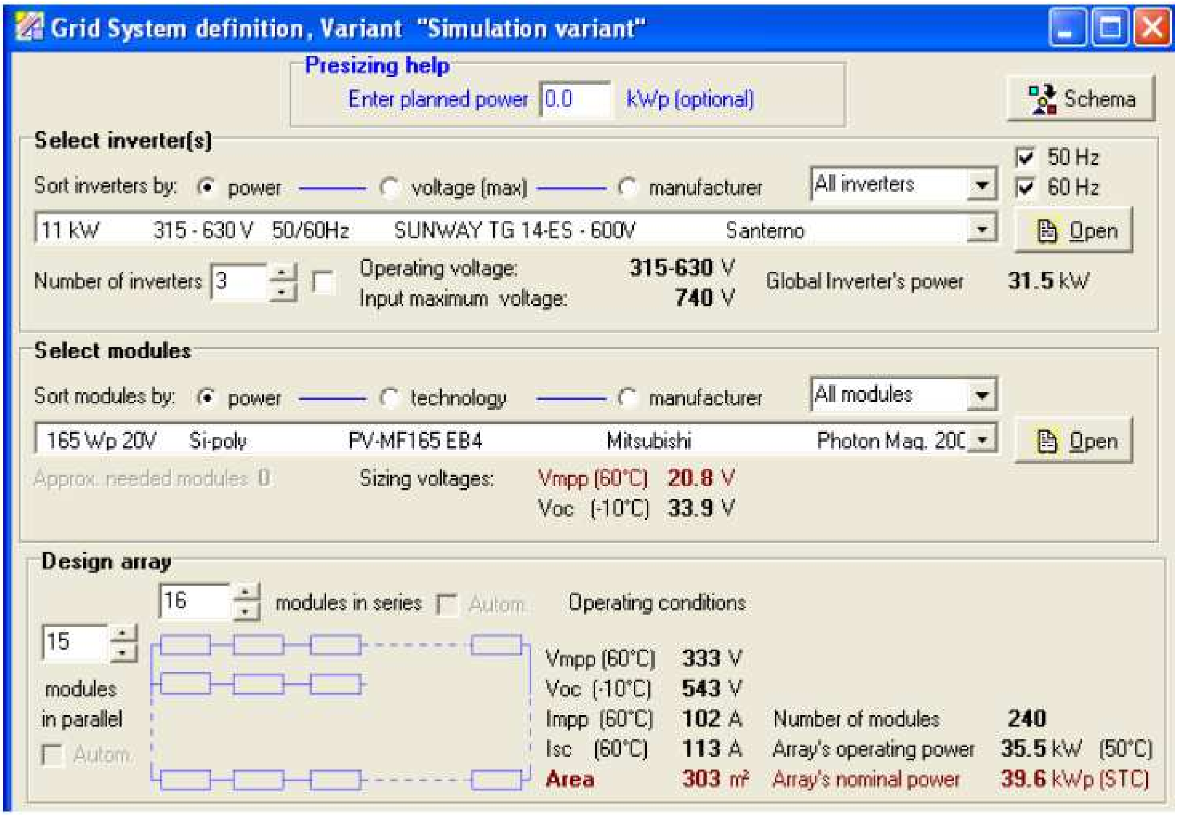
The next table shows an outline of the project's organization and simulation process**.**

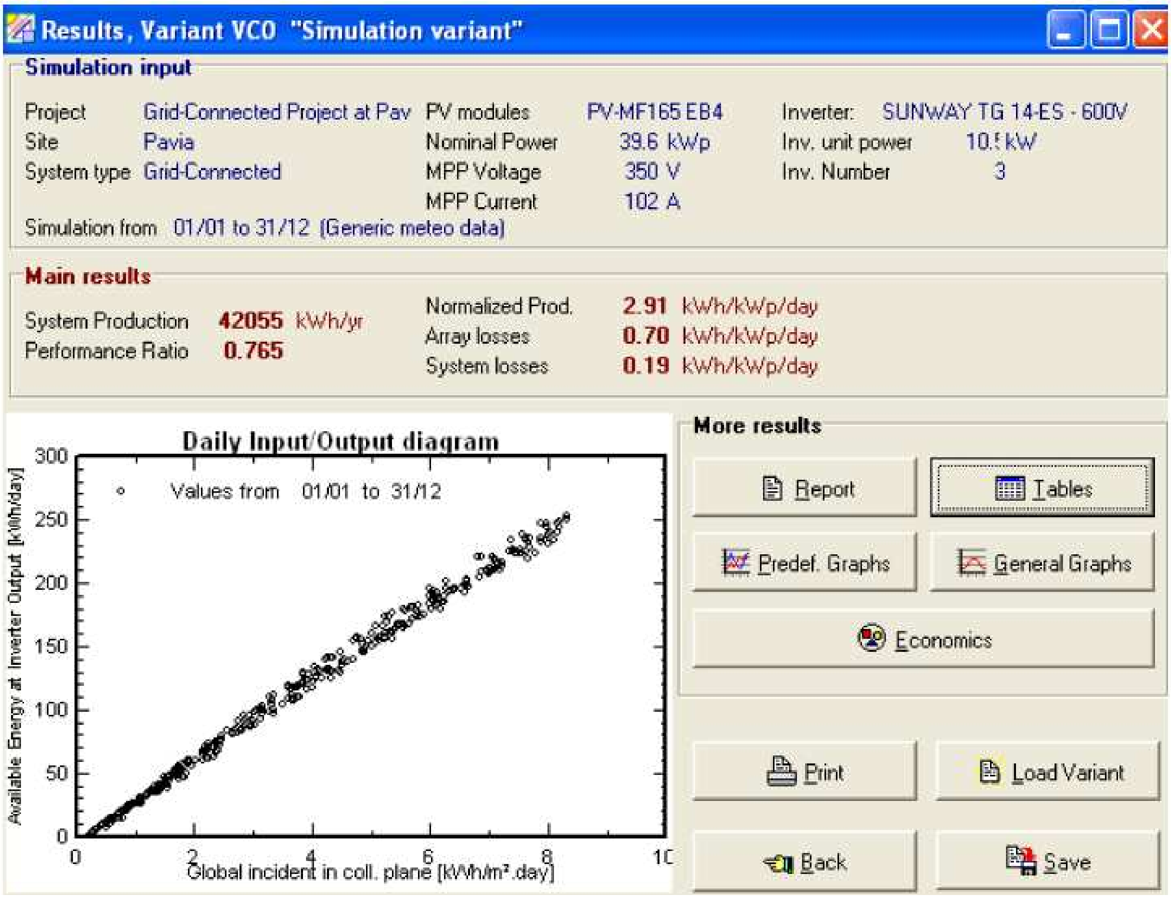

Hourly meteorological data
(Reference Year, TMY, Satellight)
Monthly meteorological data
(Sites database)
Hourly meteo measurements
(Custom, horiz. or in coll. plane)
Generation of
synthetic hourly values
Project
Specification of the site (geographic coordinates)
Hourly meteorological data
Eventually Meteorological corrections (Albedo, Altitude, etc)
Simulation variant
(Many simulation variants may be defined for a given project)
Incident irradiance in the collector plane:
Transposition from horizontal values to the collector plane
(fixed plane, tracking 1 or 2 axes, seasonal adjusment, heterogeneous fields)
If "infinite" sheds or sun-shields: mutual shadings calculation
Far shadings (Horizon definition)
The far shadings affect the whole field at a time
Near shadings (partial shadings on the field)
Shading of near objects require a detailed 3D description of the system
Shading factor for beam component: "linear" or according to modules
Shading factor for diffuse: spherical integral of the "linear" shading factor
PV array
Choice of PV modules (library)
Number and interconnections of modules
Specification of Losses (In a second step):
Module quality, Mismatch, Thermal, Wiring resistance, Incidence angle (IAM)
System
Grid-connected, Stand-alone, Pumping, DC-Grid
Choice of the components and configuration
Simulation of the system (by hourly steps)
Results for a simulation version:
Complete engineer report - Economical evaluation
Customised Tables, monthly, daily and hourly graphs. - Detailed Loss diagram
ASCII export file.

Where we can choose to print the following forms:

- General simulation parameters, which summaries all the parameters involved in a "variant"
- Detailed simulation parameters, such as Horizon (drawing+points table), Near shadings, detailed user's needs, etc,
- A pre-defined form with the main parameters and main results of this simulation,
- The detailed loss diagram
- Any specific result graph or table displayed on the screen, along with the main parameters,
- The economic evaluation sheet.

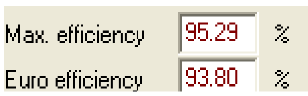
The Result dialog offers the opportunity of recalling other "variants" of the project, in order to perform quick comparisons, that then we can find in : *C: \ Archivos de programas\PVSYST4\data\Projects and its name is Pavia_Project.VC9*





- **System production: 42055 kWh/ year**

- **Normalized Prod.= 2.91 kWh/kWp/day**



1.9. PRINCIPLE OF ELECTRIC VERIFICATION

In correspondence of the least values of the temperature of job of the forms (-10 °Cs) and the maximum values of job of the same (70 °Cs) the following inequalities are verified in the software Solarius-PV:

- **MPPT VOLTAGE**

•Vm to 70 °Cs (389.33 V) major of Vmppt min. (315.00 V)
• Vm to -10 °Cs (557.63 V) smaller of Vmppt max. (630.00 V)

- **MAXIMUN VOLTAGE:**

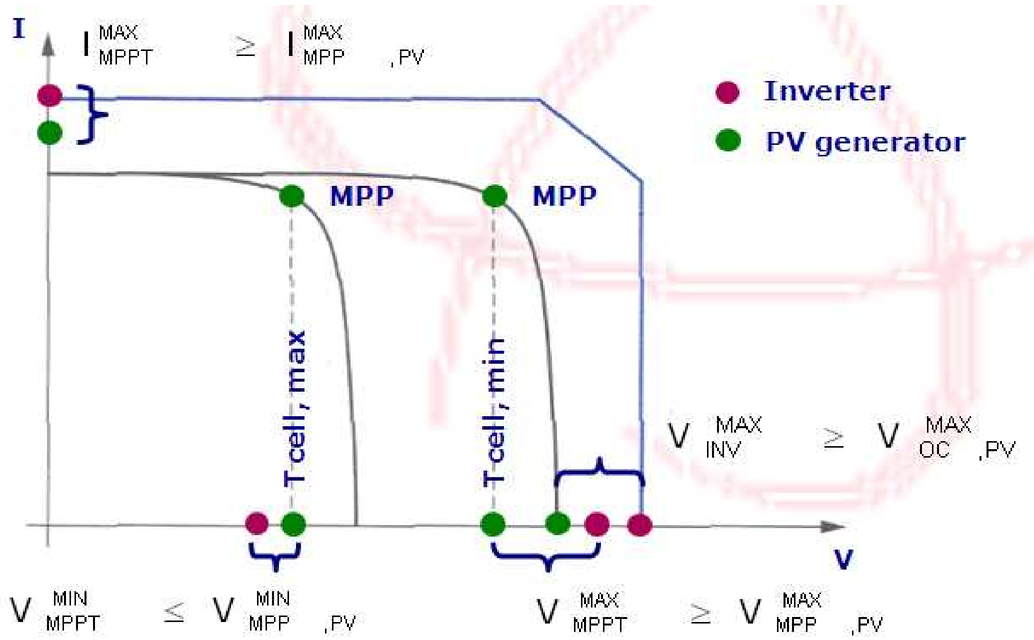
•Voc to -10 °Cs (681.63 V) inferior to the max voltage of the inverter (740.00 V)
•Voc to -10 °Cs (681.63 V) inferior to the tension max. of system of the module (780.00)

- **MAXIMUM CURRENT:**

Maximum Current produced (29.44) inferior to the current max. of the inverter (31.40)

- **SIZING**

Sizing (75.76%) inclusive among 70% and 120%



1.9.1 TESTS AND INSPECTIONS > ON SITE INSPECTIONS

- On site (acceptance and periodic) inspections

–Shadows

–Equipment

- Tests

–DC side

–AC side

–At acceptance:

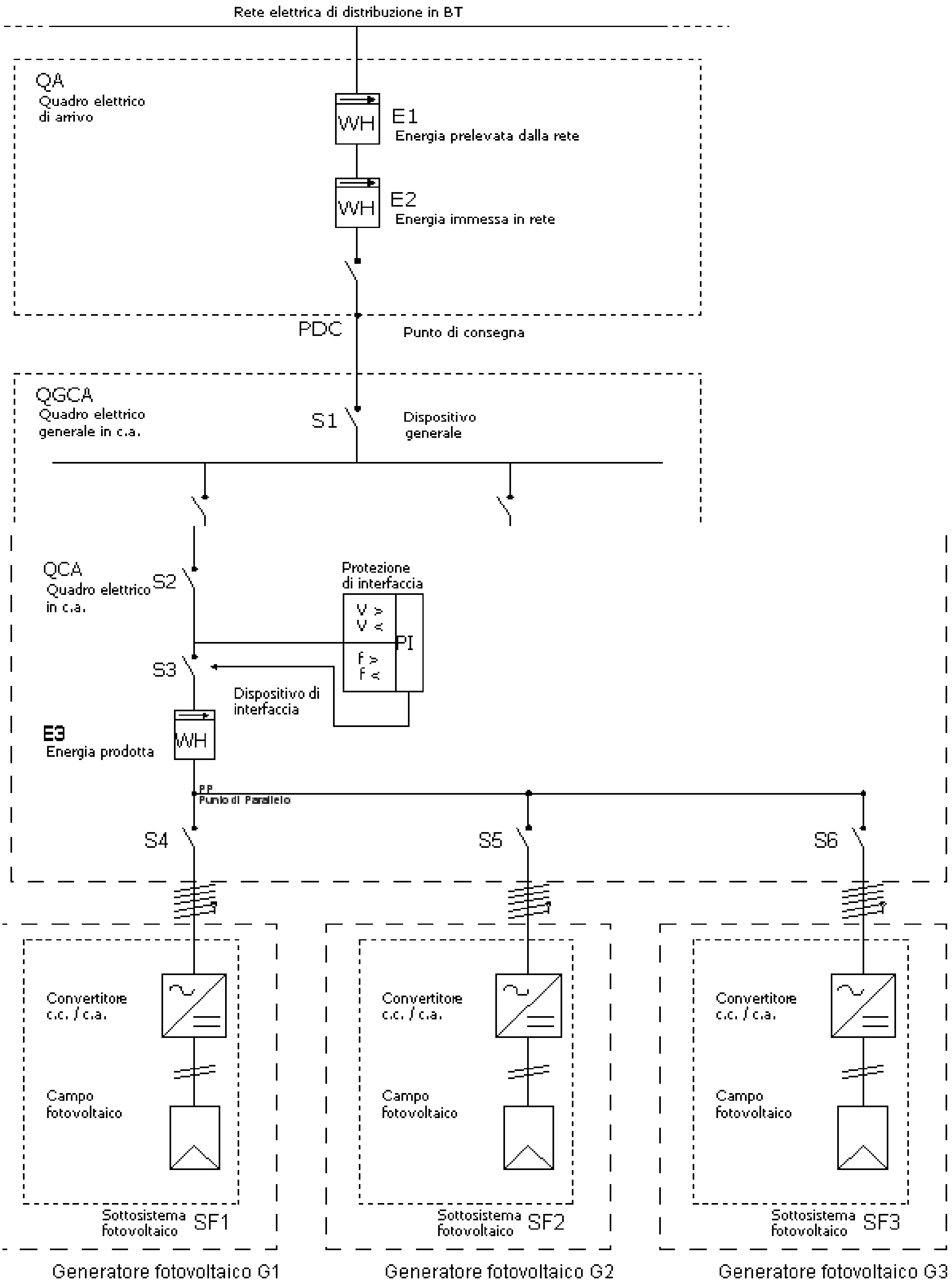
•Array voltage and current

•Circuit insulation

•Equipotential bonding

Type	Acceptance	Periodic inspection	
Module installation	Yes	Yes	Modules
Module damage	Yes	Yes	
Frame corrosion	No	Yes	
Earthing conductors damage	Yes	Yes	
Boxes damage	No	Yes	
Plate damage	Yes	Yes	
Cables type and installation	Yes	No	Cables
Mechanical and fault stresses	No	Yes	
Circuit identification	Yes	Yes	
Rack proper installation	Yes	No	Rack
Terminal installation	Yes	Yes	
Water/corrosion	No	Yes	
Fuses	No	Yes	
Earthing conductors damage	Yes	Yes	
Plate damage	Yes	Yes	
Inverter proper installation	Yes	No	Inverter
Operation and alarm signalling	Yes	Yes	
Connections	Yes	Yes	
Fan	Yes	Yes	
Plate damage	Yes	Yes	

1.10. UNIFILIAR SCHEME



CHAP II

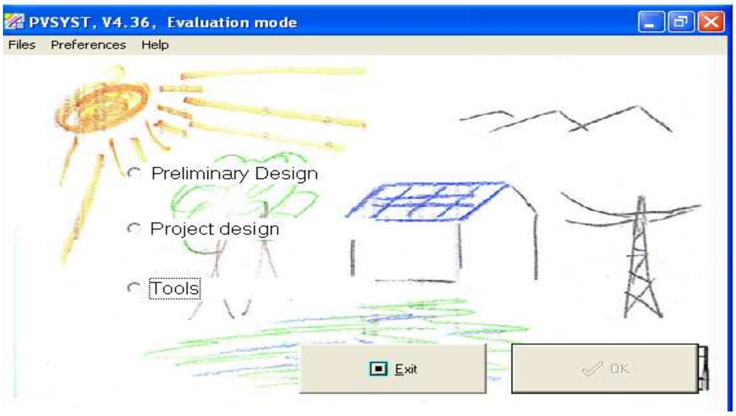
PHOTOVOLTAIC

PVSYST 4.36

CHAP II: PHOTOVOLTAIC PVSYST 4.36

2. GENERAL DESCRIPTION OF PVSYST 4.6

It´s a PC software package for the study, sizing and data analysis of complete PV systems. We are going using it to for the study of the Photovoltaic Installation in the University of Pavia.
It deals with grid-connected, stand-alone, pumping and DC-grid (public transport) PV systems, and includes extensive meteo and PV systems components databases, as well as general solar energy tools.
PVSYST V4.6 offers 3 levels of PV system study, roughly corresponding to the different stages in the development of real project:



- Preliminary Design
- Project Design
- Tools

2.1. TOOLS

This third part of PVSYST is Tool, but in order to understand better the software, it will be explained in the first time, because then all the options have a link which those following topics:

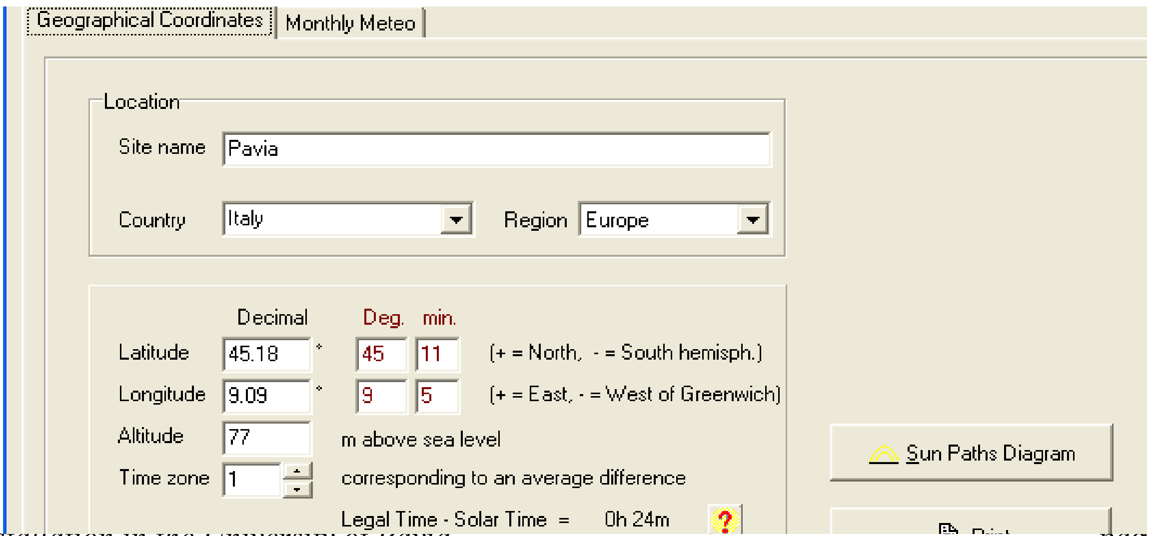
2.1.1 METEO DATABASE:

These data are issued from the database of the software Meteonorm, which summarises well-established meteorological data of about 7.700 sites in the world.

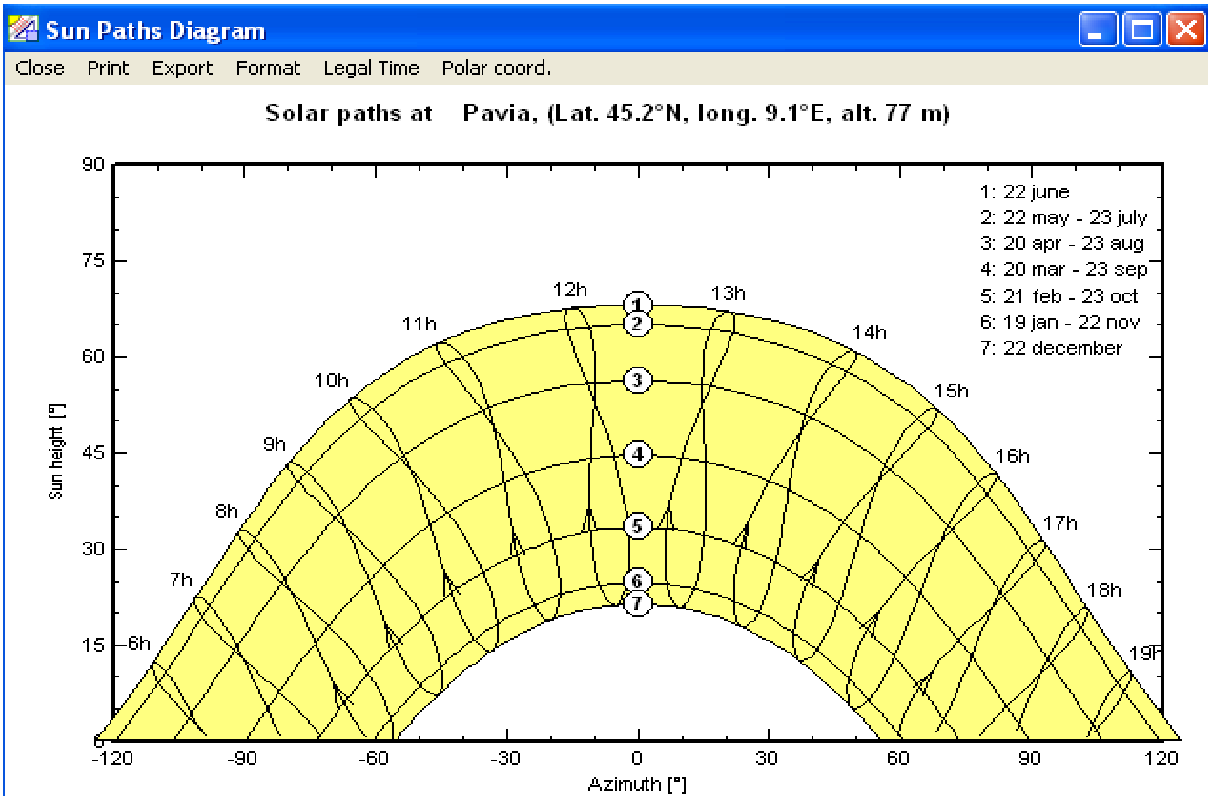
2.1.1.1. GEOGRAPHIC SITES: The PVSYST library includes the Geographic Site's definitions (latitude, longitude, altitude and time zone), as well as monthly data of the global irradiation, temperatures and wind velocity for more than 200 sites over the world. But there isn´t Pavia, although the city nearler is Milan, all after we have obtened the dates of METEONORM Version 6.1.0.11 in order to make a specific study, and then we can use it dates salved in *C:\Archivos de programas\PVSYST4\data\Projects*

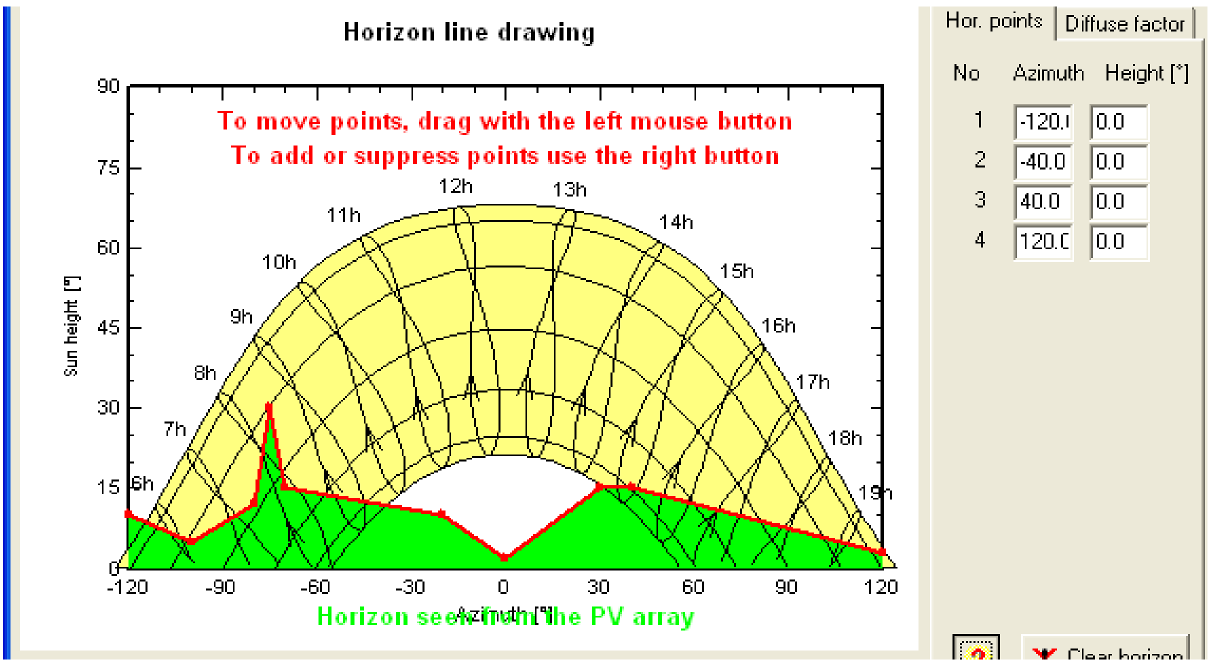
We have to see two windows:

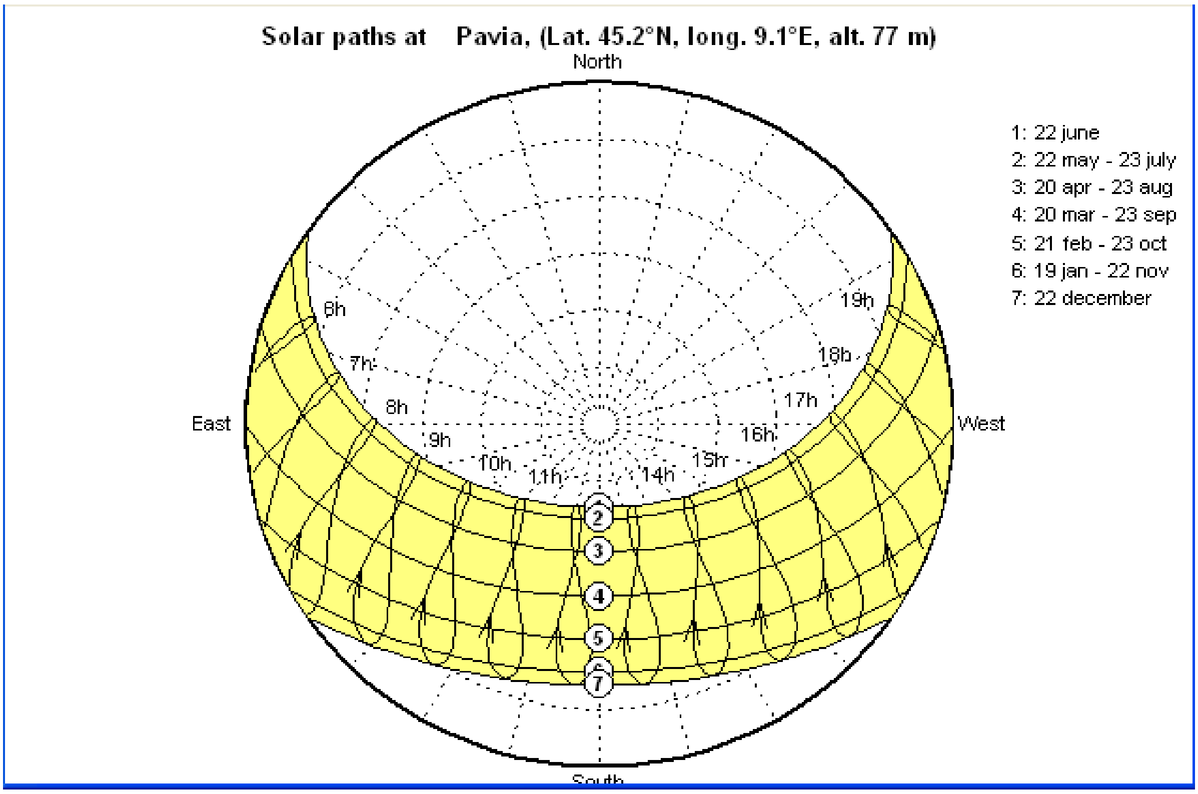
2.1.1.2. GEOGRAPHIC COORDINATES



Opening "Sun Paths Diagram" it was watched Solar Paths in polar and rect coordinates that those diagrams are a convenient way of representing annual changes in the path of the Sun through the sky within a single 2D diagram. Their most immediate use is that the solar azimuth and altitude can be read off directly for any time of the day and day of the year. They also provide a unique summary of solar position that the designer can refer to when considering shading requirements and design options.



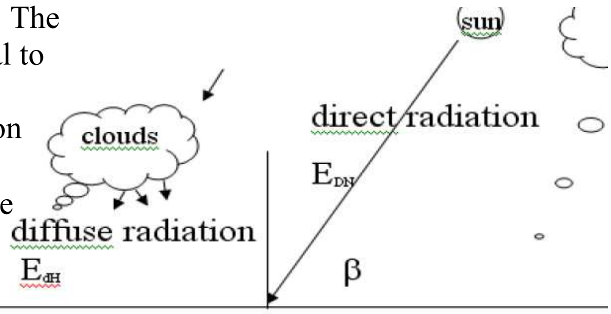




<u>Diffuse factor:</u> The solar radiation reaching the earth consists of direct and diffuse radiation.:

- Direct: portion of the radiation that has penetrated the atmosphere without having been scattered or absorbed.
- Diffuse: iscattered radiation that comes from the sky from all directions.

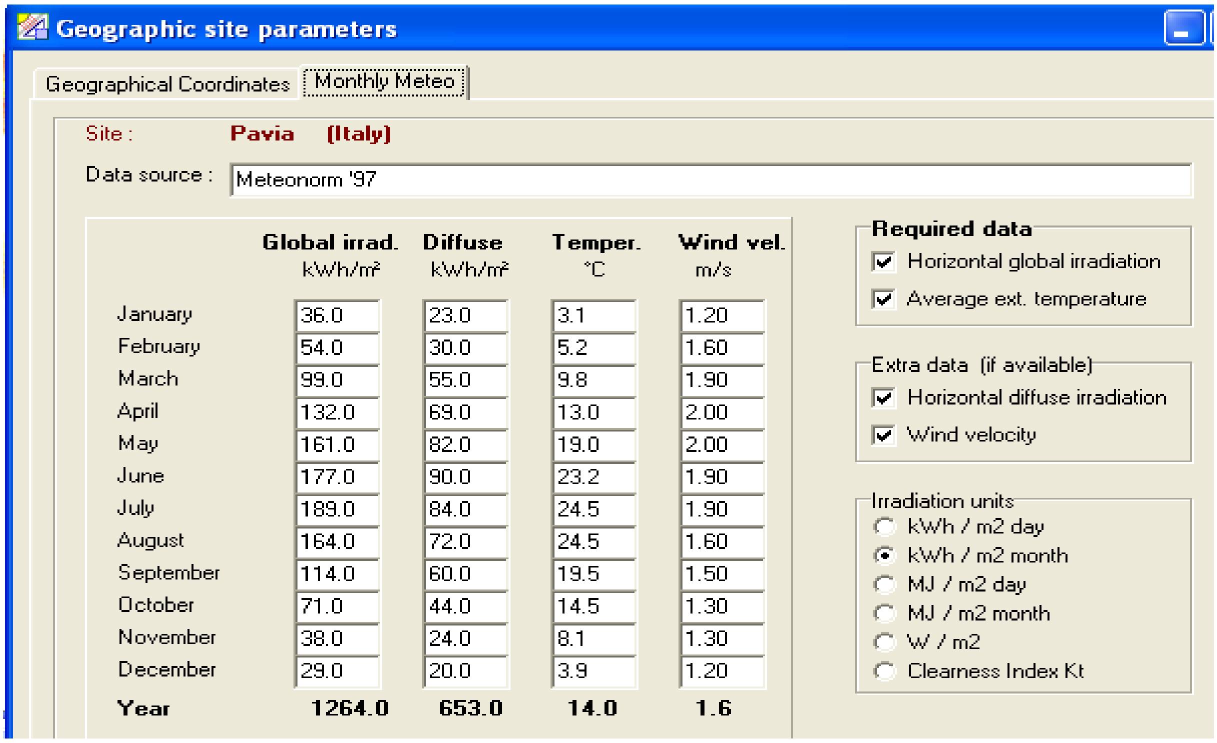
Solar irradiation on a horizontal surface: The direct radiation incident on a surface normal to its direction is called the direct normal irradiation, EDN. The direct radiation incident on a horizontal surface is therefore EDN sin β, where β is the solar altitude. The diffuse radiation from the sky is normally measured on a horizontal surface, Ed



EtH = EDN sin β + EdH

That it is applicable in general regardless of whether the day is clear or overcast. On a totally overcast day, there is only diffuse radiation (EDN = 0). On a clear day, the diffuse radiation is only a small fraction of the direct normal radiation. Since in this study the diffuse factore=1.

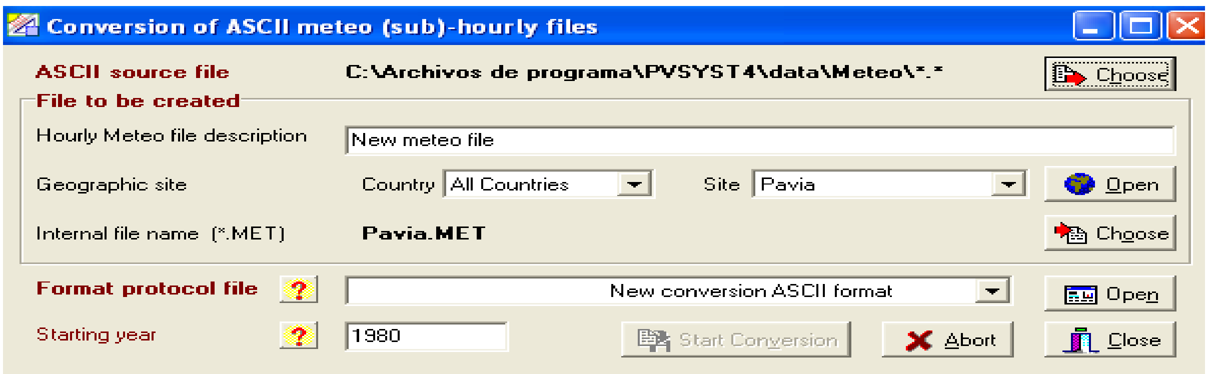
- *MONTHLY METEO*



2.1.2. SYNTHETIC HOURLY DATA GENERATION: to generate meteo hourly synthetic data from any above monthly data. We can see the same information that before and choose:

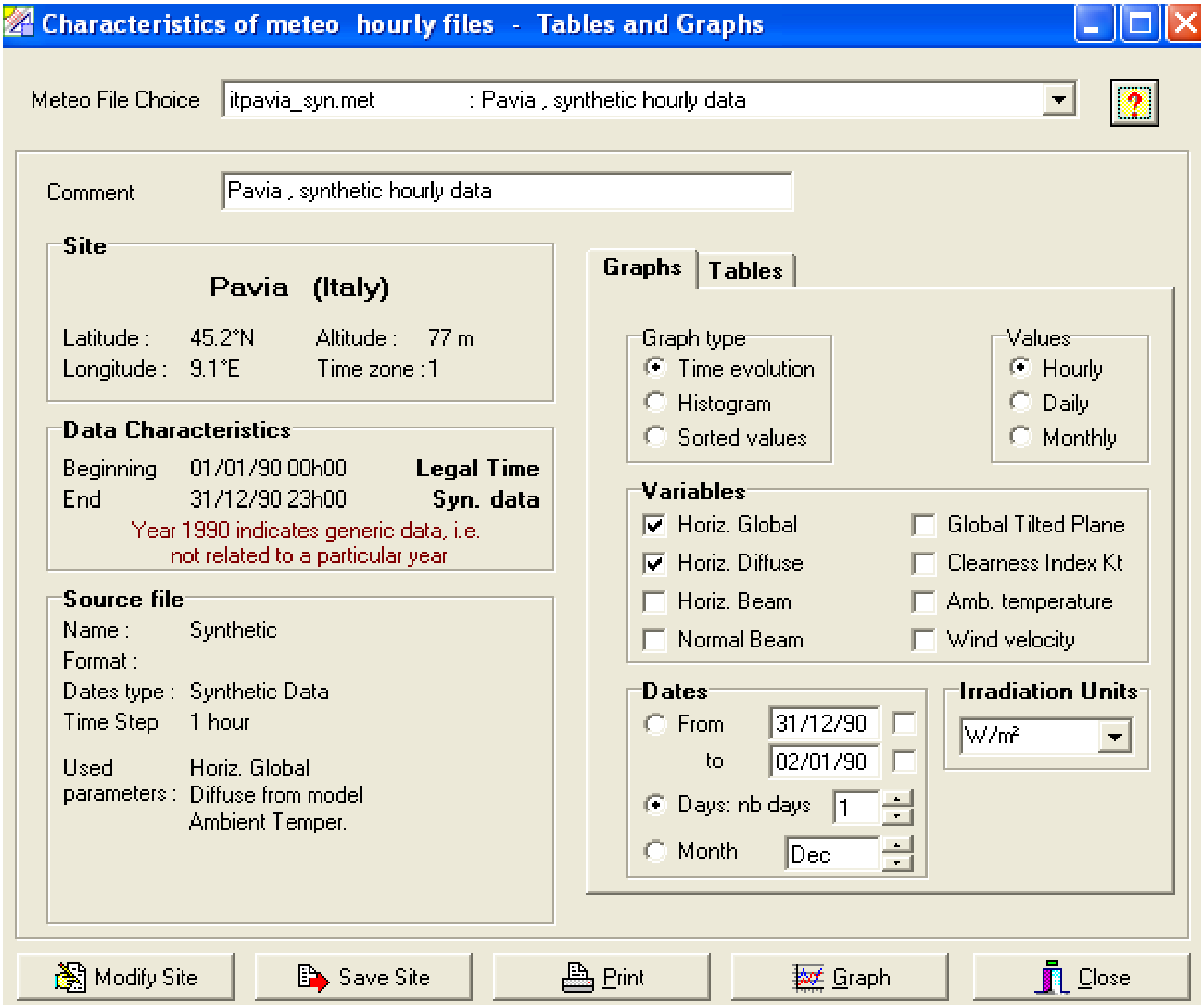
- <u>Renormalisation of Synthetic Hourly Data</u>: allows to renormalise the data as to obtain exactly the required monthly sums.Because is a random process which induces a dispersion of the monthly values, roughly corresponding to the statistical dispersion for different years.
- <u>Region Typology is only used for temperature synthtetic hourly profile generation:</u> Algorithms for temperatures generation have been established upon Swiss data, according to these region typologies. But the result is not very sensitive: the most important effect is the mist, and for any site its choice will not induce great variations of the temperature profile.

2.1.3. IMPORTING METEO DATA FROM EXTERNAL DATABASES: allows the use of meteo data from the most popular databases sources available from the Web or by other means. But we have used to Meteornorm because it´s the best recommended.



2.1.4. IMPORT ASCII METEO FILES: allows to import meteo hourly or daily data in almost any ASCII format.

2.1.5. METEO TABLES AND GRAPHS: powerful visualising and analysing tool for hourly meteo data files.



The geographical characteristics are stored in an object identical to the geographical site definition, which may be edited and modified. The meteo file, written in a binary format, cannot be read using a text editor. This tool offers a powerful mean of visualising and analysing meteorological data in graphical or tabular form. Printings or data export (using clipboard as well as ASCII file) can be easily performed for any time period, allowing the use these data in other software.

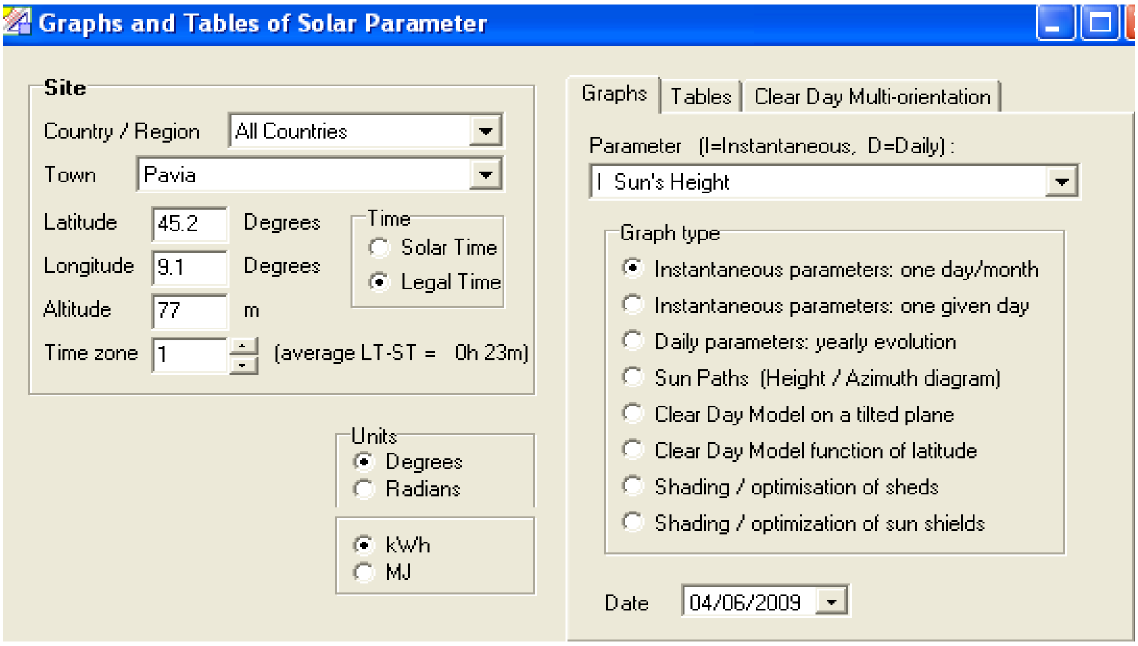
The basic data of the file: Global and Diffuse horizontal irradiance, ambient temperature and wind velocity; derived values like beam component, clearness index Kt, or global irradiance on a tilted plane. All these data are available in hourly, daily or monthly values.

Graphs can be obtained as time evolution (selected periods), values distribution histograms or sorted values (cumulated histograms).

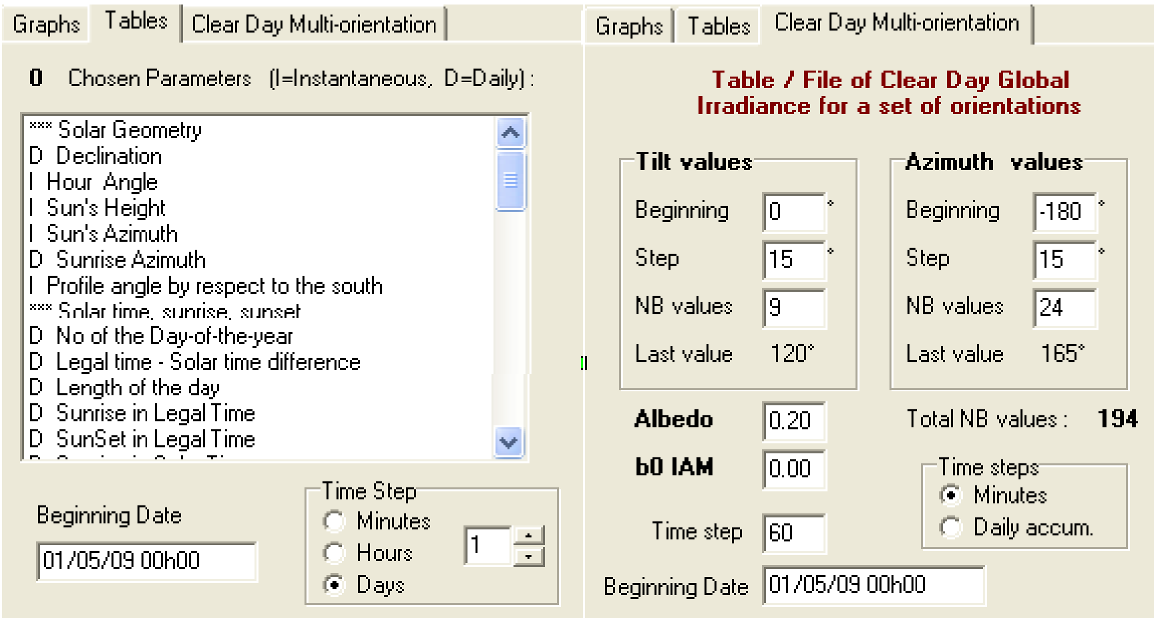
2.2. SOLAR TOOL B OX:

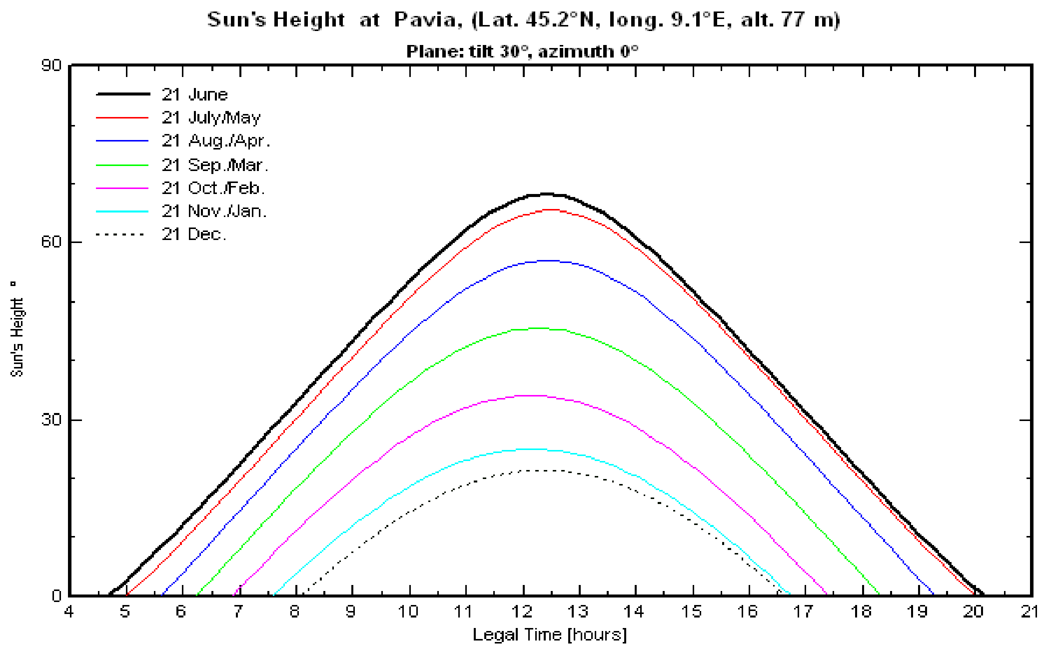
2.2.1. GRAPH/TABLES OF SOLAR PARAMETERS:

Displays solar geometry and Clear Sky irradiation on planes.There are tree windows where we have to choose the parameters and Graph type and the options of Graphs, Tables and Clear Day Multi-orientation in orden to get and can compare the optimal tilt and azimul angle for optimizing the Solar Photovoltaic Energy capture on sunny and cloudy days and it´s unquestionably the use of a Solar Tracking System but in our project, it isn´t necessary be cause in the location chosen there aren´t shades and this installation it´s more expensive. Therefore, improving the solar energy capture on the worst days is important to minimize the solar and storage system size and maximize the overall use of the installation fueling system



In this graph we can see the sun´s height in the different months to then can calculate the shadings and the radiation that incides on the collectors.





In the window "Clear Day Multi-orientation" we can chose the optimal tilt and azimuth angle doing a comparison of the irradiances in a year that can select the time in minutes, hours or days, and this study consist of changing with a step chosed, the tilt and azimuth values angle.
In our project the optimal tilt angle range from 30º to 36º, depending on the different softwares used. Since we hava decided to select 30º, because the results are similar, and specifically in this software the results are better and is easier to look for the structure support.

<u>Array incidence loss (IAM: "Incidence Angle Modifier")</u>: The incidence effect corresponds to the weakening of the irradiation really reaching the the PV cells's surface, with respect to irradiation under normal incidence. In principle, this loss obeys Fresnel's Laws concerning transmission and reflections on the protective layer and on the cell's surface. In practice, it is often approached using a parametrisation called "ASHRAE", depending on one only parameter **bo**: **FIAM = 1 - bo · (1/cos i - 1), with i = incidence angle on the plane.**

For single-glazed thermal solar module -> bo =0.1. But in a PV module, the lower interface, presents a high refraction index and our specific measurements on real crystalline modules actually indicate a value of bo = 0.05 .In our project is 0.

Clear Day Global Tiltes Irradiances for Pavia

Close Print Export Help

Clear sky model at Pavia, (Lat. 45.2°N, long. 9.1°E, alt. -month +month

W/m² Legal Time	Global Horiz.	Tilt=30° Azim=-15°	Tilt=30° Azim=-0°	Tilt=30° Azim=15°	Tilt=30° Azim=30°	Tilt=30° Azim=45°	Tilt=30° Azim=60°	Tilt=30° Azim=75°
31/05/09 00h00	0	0	0	0	0	0	0	0
31/05/09 01h00	0	0	0	0	0	0	0	0
31/05/09 02h00	0	0	0	0	0	0	0	0
31/05/09 03h00	0	0	0	0	0	0	0	0
31/05/09 04h00	0	0	0	0	0	0	0	0
31/05/09 05h00	12	10	10	10	10	10	10	10
31/05/09 06h00	123	92	35	27	27	27	27	27
31/05/09 07h00	304	301	214	131	57	35	35	35
31/05/09 08h00	494	534	441	349	262	188	130	93
31/05/09 09h00	667	743	661	573	487	408	341	291
31/05/09 10h00	807	905	843	772	697	623	556	499
31/05/09 11h00	904	1005	971	924	869	808	748	690
31/05/09 12h00	950	1036	1031	1014	984	945	898	847
31/05/09 13h00	942	994	1021	1034	1034	1020	993	955
31/05/09 14h00	881	885	940	983	1012	1026	1022	1002
31/05/09 15h00	770	718	795	863	920	960	981	981
31/05/09 16h00	619	509	599	686	763	825	868	890
31/05/09 17h00	439	282	374	466	554	630	689	729
31/05/09 18h00	249	76	153	235	315	389	452	499
31/05/09 19h00	78	24	24	49	93	135	174	205
31/05/09 20h00	0	0	0	0	0	0	0	0
31/05/09 21h00	0	0	0	0	0	0	0	0
31/05/09 22h00	0	0	0	0	0	0	0	0
31/05/09 23h00	0	0	0	0	0	0	0	0

2.2.2. ELECTRICAL BEHAVIOUR OF PV ARRAYS:

For a better understanding of the electric phenomena involved when connecting several modules together in arrays.

2.2.2.1. REVERSE CHARACTERISTICS

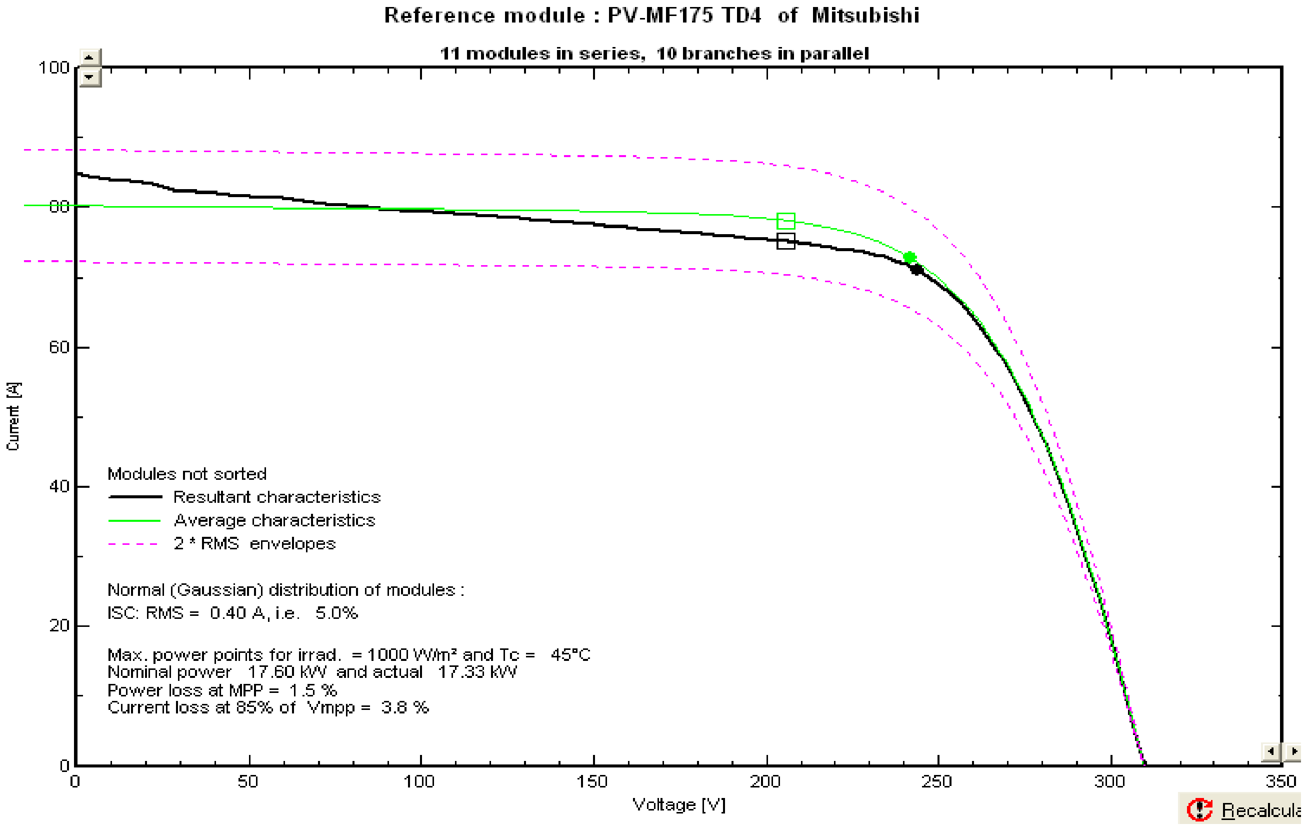
This tool presents the operating of a PV module when it is polarised towards negative voltages, when the cells are different, or if the irradiation is not homogeneous.There are 3 typical situations:

This tool presents the operating of a PV module when it is polarised towards negative voltages, when the cells are different, or if the irradiation is not homogeneous. There are 3 typical situations:

- **"One single PV cell"**: under bright irradiance, reverse bias of the cell rapidly involves high powers to be dissipated, as the current is already at least at the cell Photocurrent level.
- **"PV module without by-pass diode":** the solid line represents the whole module characteristics, that is, all cells in series. With identical cells, the total dissipated power is equally distributed on every cell. If one cell has a lower photocurrent - due to its quality or shading – or a better BRev, then its voltage will follow its own reverse curve, and at the imposed common current it can produce a much higher power than for the other cells, therefore

giving a rise of temperature.

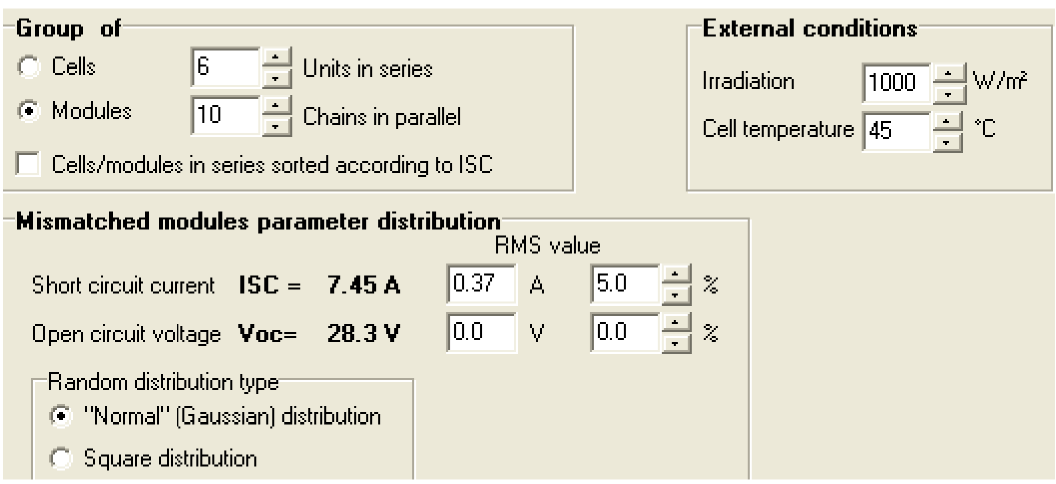
• **"PV module with by-pass diode":** the module reverse voltage is limited to the "forward" voltage of the diode (about 0.7V for one diode, 1.4V for 2 diodes, etc). The excess current is drawn by the diode, and cannot give rise to excess powers in the diode since the voltage stays very low.



2.2.2.2. MISMATCH

The program simulates the connection of any number of elements in series and in parallel - by affecting to the I/V model parameters of each element a random dispersion.

The parameters that can be modulated are:



- the short-circuit current: **Isc** (analogous to a non-homogenous irradiance distribution),
- the open circuit voltage: **Voc** (which can also reflect temperature differences).

This calculates each characteristic according to the standard model, and then adds up point-by-point the voltages of the elements in series and the currents from series in parallel. It then obtains the overall resultant characteristic of the field, and the program traces the "mean" characteristic and two envelope-characteristics which can be chosen as 2-RMS values, or as extreme random values encountered in the sample. It evaluates the Power loss at maximum power point, and at a fixed operating voltage, with respect to the nominal case.

2.2.2.3. ARRAY WITH SHADED CELLS

Studying the wiring of the PV fields, in such a way that the foreseen shadings simultaneously affect the smallest number of series possible. It evaluates the energy dissipation of this cell for various operating points, and its resultant temperature by making reasonable hypotheses for the thermal loss factor, adjusting the irradiance, the module temperature in normal operation, and the shading fraction.
These behaviours are studied in a marginal situation where only one single cell is disturbed. Because of this the in our project isn´t used. We can visualise different cases: modules without protection diodes o with by-pass diode.

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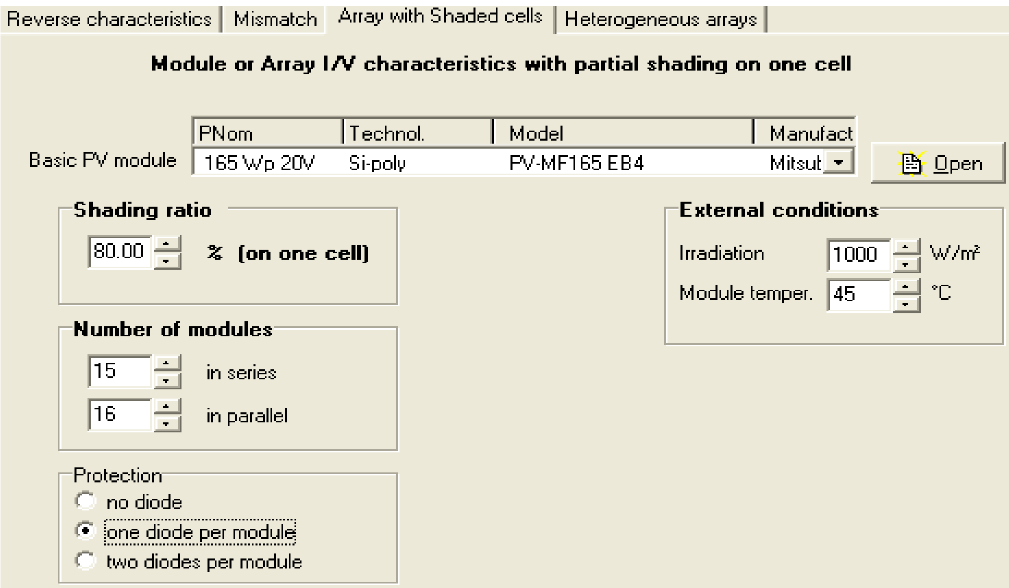
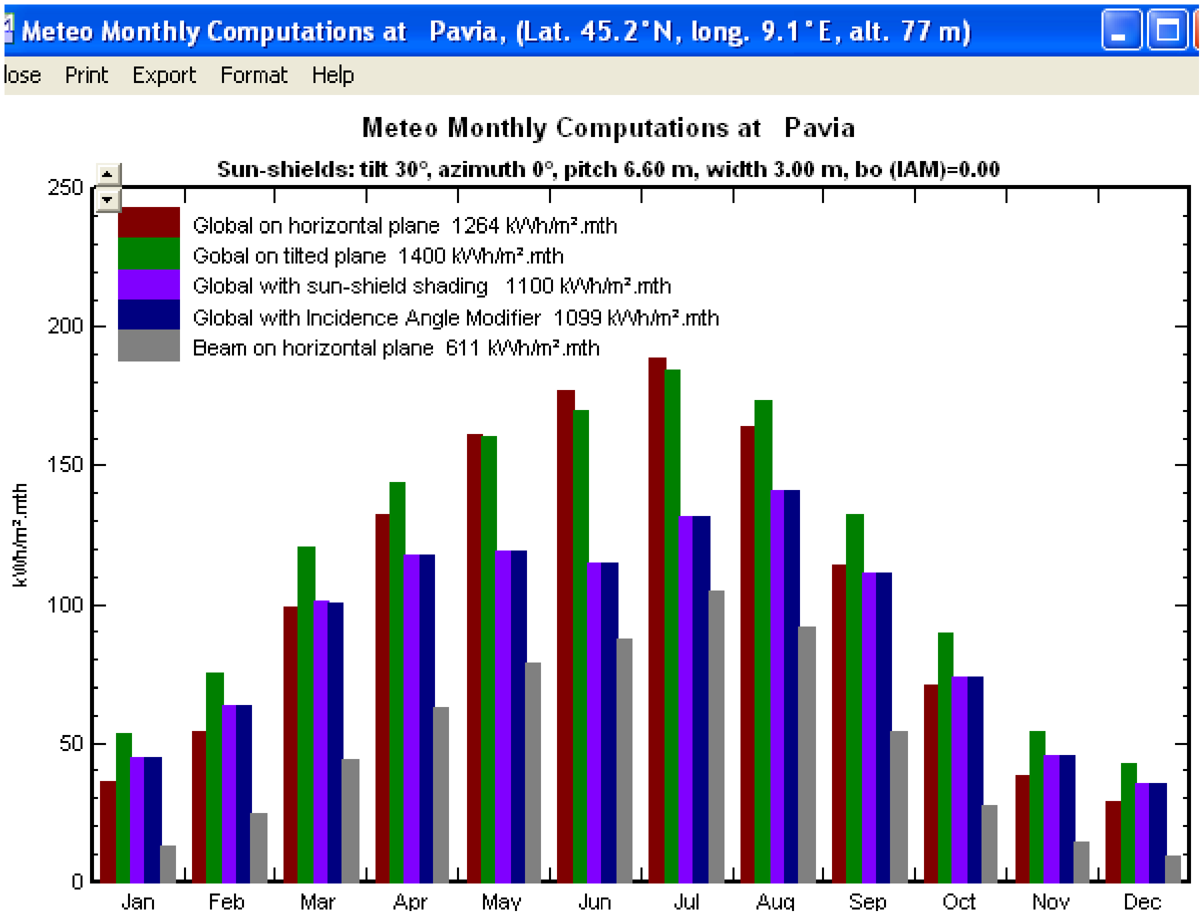
2.2.2.4. HETEROGENEOUS ARRAYS: It shows the characteristic of two fields, connected in parallel, which can be different in orientation and collector's number, in order to evaluate the dynamic behaviour during the day.



2.2.3. MONTHLY METEO COMPUTATION

Quick meteo evaluation using geographical site database, with horizon, tilt, sheds and sun-shields, IAM effects.

This method takes advantage of so-called "average months" properties. With real meteo data of a given month, when constructing an "average day"(that we can apply all the corrections using the solar geometry) by averaging separately the irradiances at each hour, we obtain an average profile which is very close to the "Clear day" model profile, with amplitude reduced in such a way that the day integral matches the monthly global value. This procedure avoids constructing synthetic hourly values, and gives instantaneous evaluations with very acceptable accuracy.



2.2.4. TRANSPOSITION FACTOR: field orientation optimisation and evaluation tool.

2.2.5. OPERATING VOLTAGE OPTIMIZATION. This tool evaluates the PV-array performance as function of a fixed user's operating voltage.
The MPP operating voltage of a PV array varies along the day and the year, according to Irradiance and Module temperature. Estimating the performances for a given fixed voltage is depending on:The climate, the meteo distribution, the PV plane orientation, the Array composition (PV module, number of modules in series/parallel), the protection diode voltage drop, the Array wiring resistance.The Relative average power yield (or efficiency) for different user voltage values is computed using meteo hourly data, over a given period.

PLANE ORIENTATION:

PVSYST supports simulations with one of the plane orientation modes:

- *Fixed tilted plane:* define the Plane tilt and azimuth.
- *Seasonal tilt adjustment*: the plane tilt may be adjusted for winter and summer chosen months.
- *Tracking, two axes:* the limit mechanical angles of the tracking device (in tilt and azimuth) should be defined, and are taken into account during the simulation.
- *Tracking, tilted axis:* the axis's tilt and azimuth should be defined. The rotation angle is called Phi (=0 when plane azimuth = axis azimuth), with the same sign conventions as for plane azimuth. Limits on the Phi stroke are required.
- *Tracking, horizontal axis*: the orientation axis is defined as the normal to the horizontal axis. Stroke limits should be defined (here Phi = plane tilt), from lower limit (minimum -90° = vertical north) to upper limit (maximum 90° = vertical south).
- *Tracking sun-shields:* which may yield solutions to the difficult optimisation between sun protection and PV production. For full efficiency this should involve a Backtracking control strategy.
- *Double orientation:* allows to define two collector planes with different orientations. You should define the fraction of the field allocated to each orientation.

2.3 PV COMPONENT DATABASE:

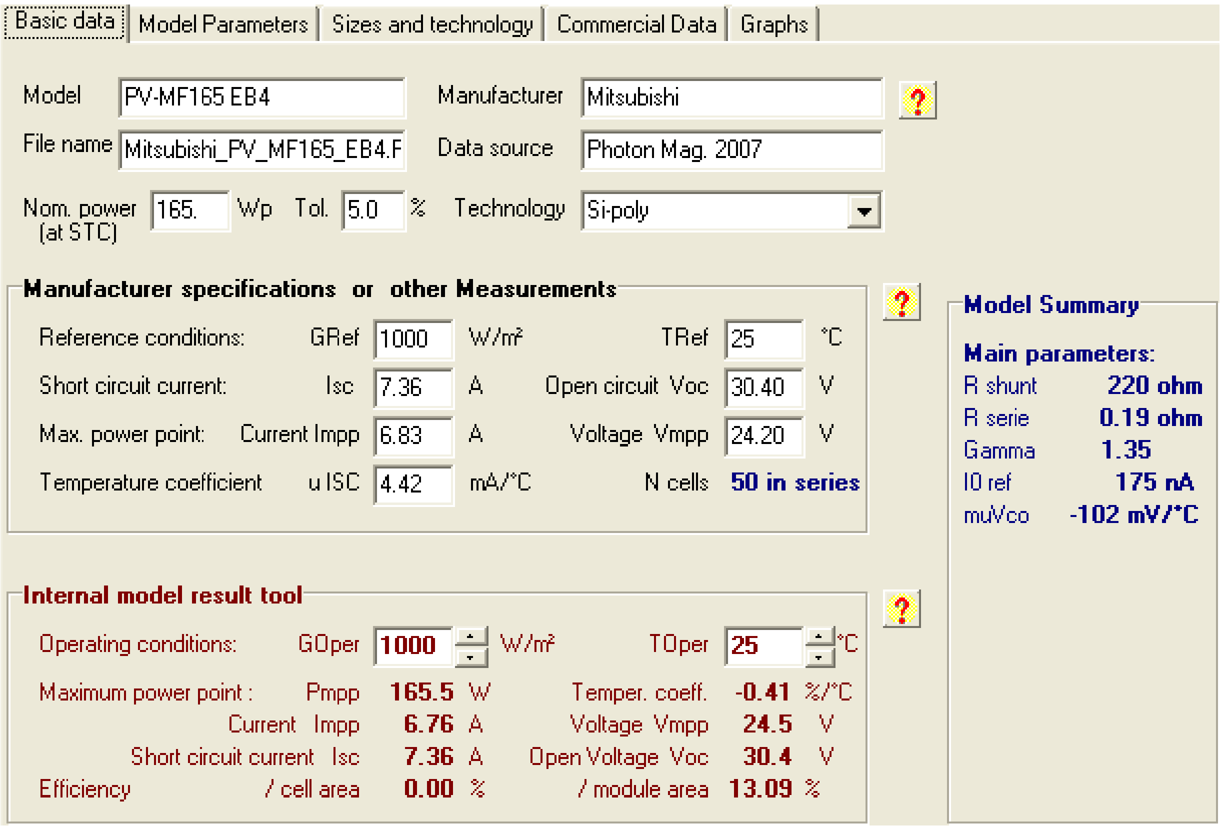
2.3.1 PV MODULES

All parameters related to a given PV module, as well as graphs of its behaviour, are available in the PV-module dialog which includes several definition sheets.

2.3.1.1. BASIC DATA, which holds the module identificators and main electrical characteristics:

<u>Module identifiers:</u>

- *Model and Manufacturer* will appear in the module choice lists.
- *Data source* usually refers to the main parameter measurement source (most often Manufacturer, may be an independent institute or your own measurements).
- *Nominal power* is the rated power specified by the manufacturer at STC. It will be used to determine the "installed power" of systems, which is involved namely in the normalised performance coefficients.
- Tolerance is the rated limits of the Nominal power dispersion, given by the manufacturer. The lower tolerance limit could be used in the Module Quality Loss specification.
- *Technology* gives choice for the main technologies available on the market. Except for Crystalline cells - for which the standard "One-diode" model is suitable - the "Advanced" button allow for correcting this model in order to match the "Thin films" and other special behaviours.



Manufacturer Specifications or Other measurements

These parameters are the main electrical module characteristics, available in any manufacturer data sheets. They are usually given for STC, but the program accepts measurements performed under other conditions to establish it's model, allowing for on-site measurements in external conditions.

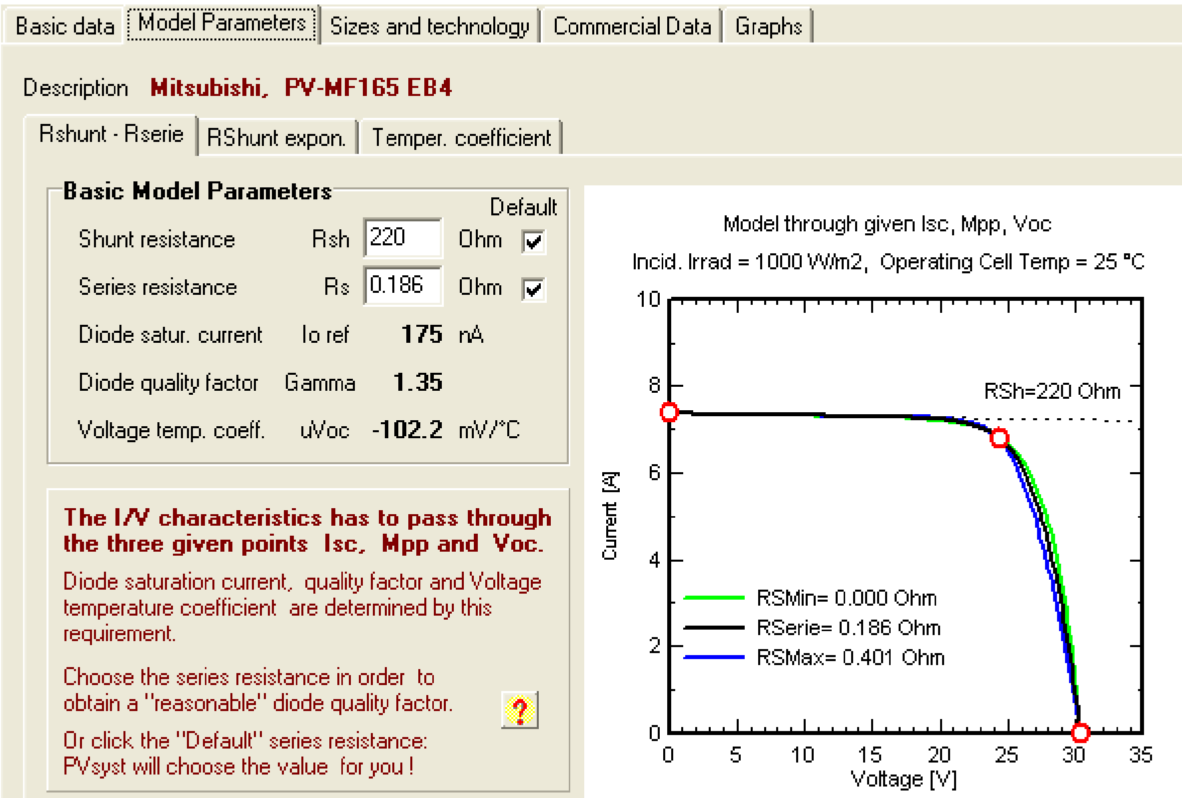
These parameters therefore include:
- *Gref and Tref:* the reference irradiation and module temperature conditions during measurements.
- *Isc and Voc:* module short circuit current and open circuit voltage at these given conditions.
- *Impp and Vmpp*: any operating point in the region of the maximum power point at these given conditions.
- *uIsc* : current temperature coefficient, the only among these parameters which is rarely available. This has only weak influence on the module behaviour. When not known, it can be taken as about 2.3 mA/°C.

Internal model result tool

After defining these basic parameters, the program still needs the definition of additional parameters - i.e. Shunt and Series resistance, as well as the number of cells in series - to establish the One-diode model parameters.

This special tool displays the module operating parameters calculated by the PVSYST model, for any given irradiation or temperature conditions.

2.3.1.2. MODEL PARAMETERS, specifies some additional parameters necessary to the PV "one-diode" model, and calculates the model unknowns.

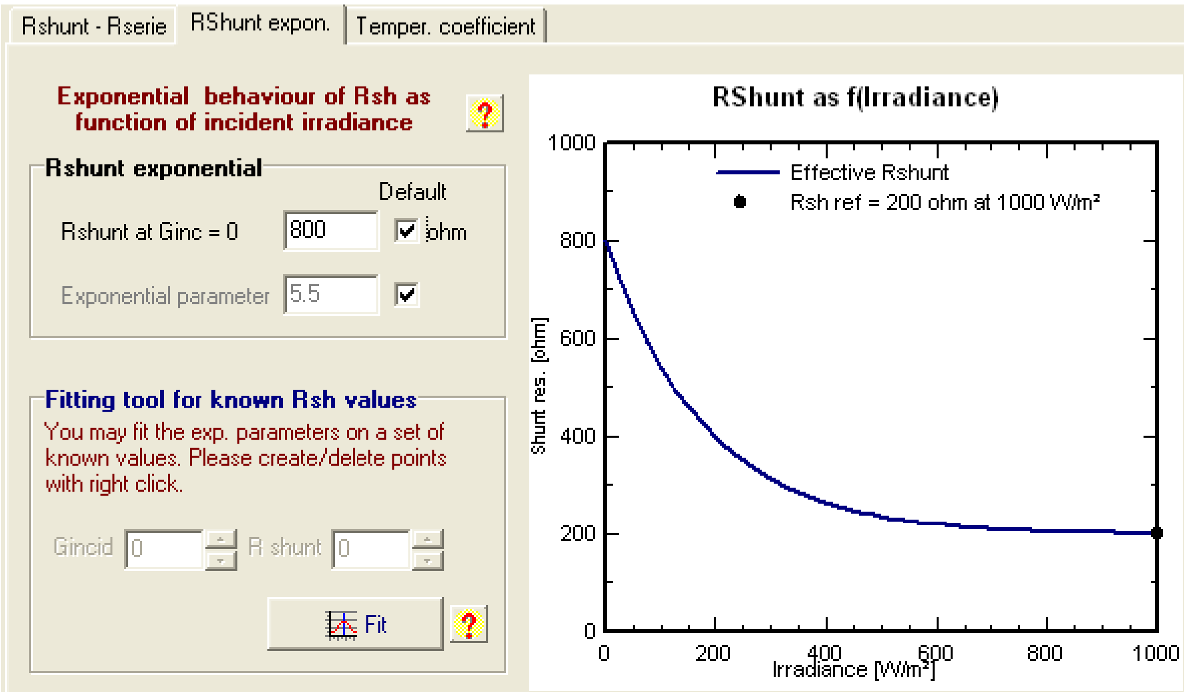


The "Basic parameters" sheet includes an "Advanced" button for defining Special parameter for thin film modules, to be used in the modified "one-diode" model for thin films.

This little tool allows for adjusting the exponential parameters, according to some known Rshunt values at different irradiances. The Rshunt value can be obtained on the basis of measured I/U characteristics of the module. Rshunt is the inverse of the slope around V=0 (i.e. the short-circuit point at Isc).

- <u>Rshunt exponential correction vs Irradiance:</u>

The shunt resistance Rsh : corresponding to the inverse of the slope of the I/V curve around V=0 - is considered as a constant parameter in the standard one-diode model. But it is easy to observe on amorphous I/V curve families that this slope decreases with the irradiance.

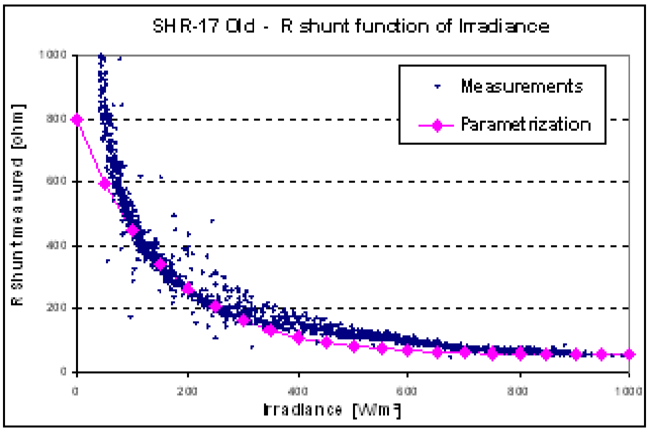


This distribution may be approximated by the following exponential expression:

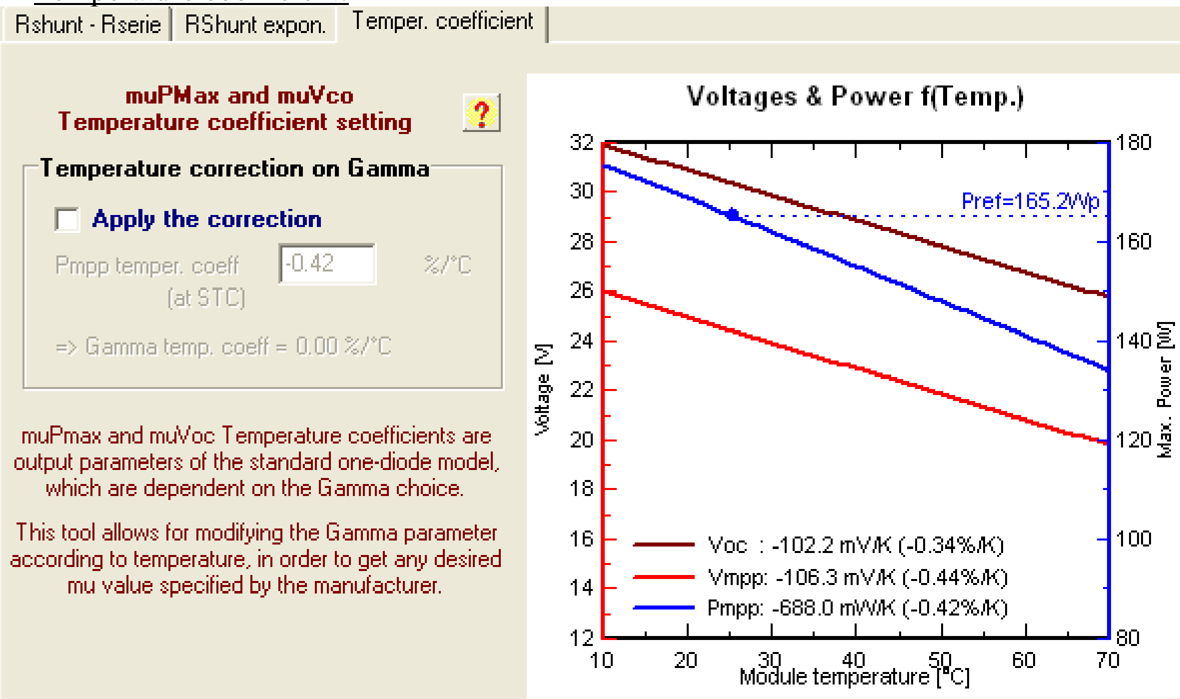
$$\mathbf{Rsh = Rsh(Gref) + [\, Rsh(0) - Rsh(Gref)\,] \cdot exp(-Rsh\ exp \cdot (G / Gref))}$$

The next figure shows the measured Rsh behaviour over our measured sample:

We observed a similar behaviour on all our measured data (including the Si-Crystalline and CIS modules). And curiously, all data may be rather well approached using a unique value Rshexp = 5.5.Therefore this value is set as default value in Pvsyst. In this expression there are 2 unknown parameter left: Rsh(Gref), i.e Rsh in the standard model, and Rsh(0). which may be determined on measured data, but are not available in the usual manufacturer's data sheets.



- <u>Temperature coefficient:</u>



In the standard one-diode model, the temperature behaviour is essentially determined by the expression of diode saturation current Io, which is exponentially dependent on the Egap and the Gamma parameters. This expression fixes the muVco and muPmax temperature coefficient values, which are therefore a result of the model.
Remember that the Gamma value is determined in correlation with the Rserie choice, which can vary from 0 to Rsmax. But some manufacturers specify temperature coefficients muVco, which are not always compatible with this Rserie allowed range.

It is the reason why PVsyst allows for modifying the temperature behaviour by introducing a linear variation of Gamma with operating Temperature:

Gamma = Gamma0 + muGamma ·(Tmod - Tref)

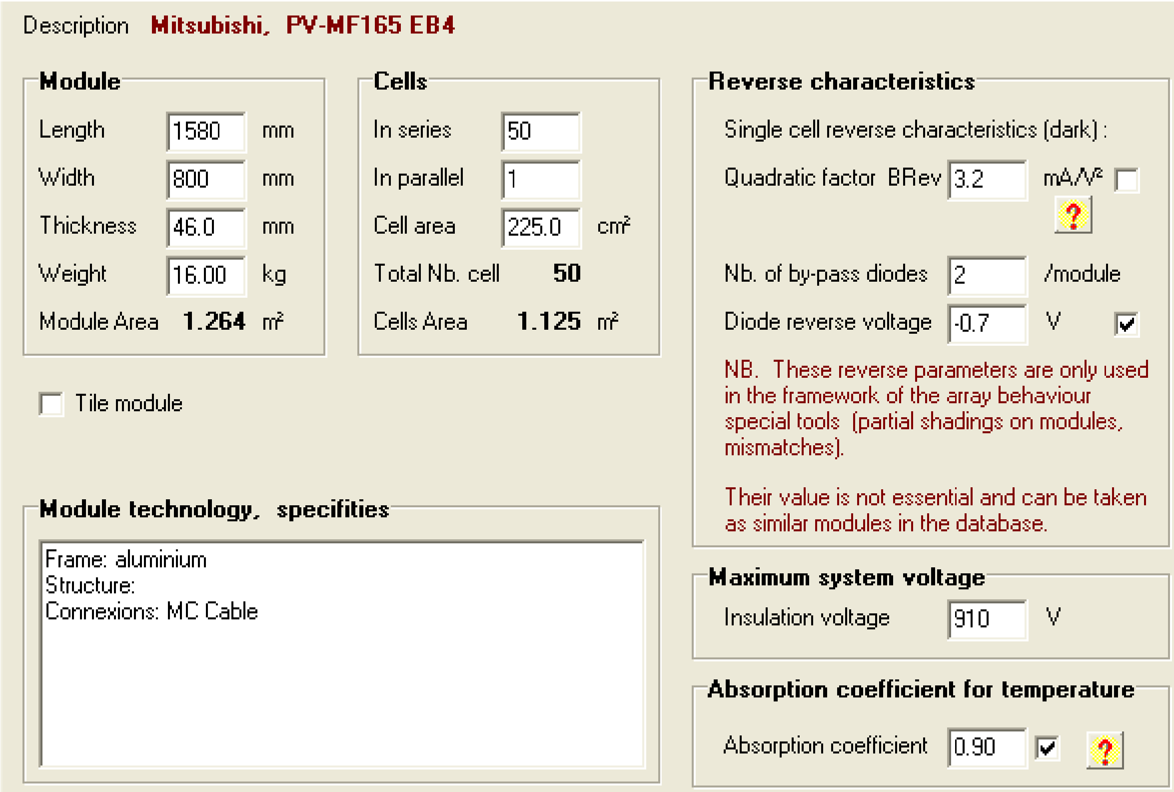
The user specifies a required muPmpp, and PVsyst determines the suited "mugamma" correction factor:
The tool shows a graph of the induced variations on muVoc, muVmpp and muPmpp.
But this tool is made available for all modules, but it is not recommended (or only as a weak correction), after all we don´t bear this in mind.

2.3.1.3. SIZE AND TECHNOLOGY, with physical and secondary characteristics that we can found on the catalogue :

<u>Module:</u> Shows the physical characteristics in order to know the module area, that isn´t different to Cells Area that it´s the area of each cells that have a dimensions: 156 · 156 mm

<u>Reverse characteristic factor</u>
Empirically, the behaviour of the cell´s characteristics under reverse polarisation is quadratic with the applied voltage. This results is from our own measurements, and confirmed in ref:

$$\mathbf{Irev = IL + Brev\ (V + Rs \cdot I)^2 \quad -\!\!\!->> \quad for\ \ V < -Rs \cdot I}$$



This expression could be valid till the avalanche zone (Zener), but in reality the dissipation in the cell which varies as the cube of the reverse voltage reaches a destructive limit well before this elbow.

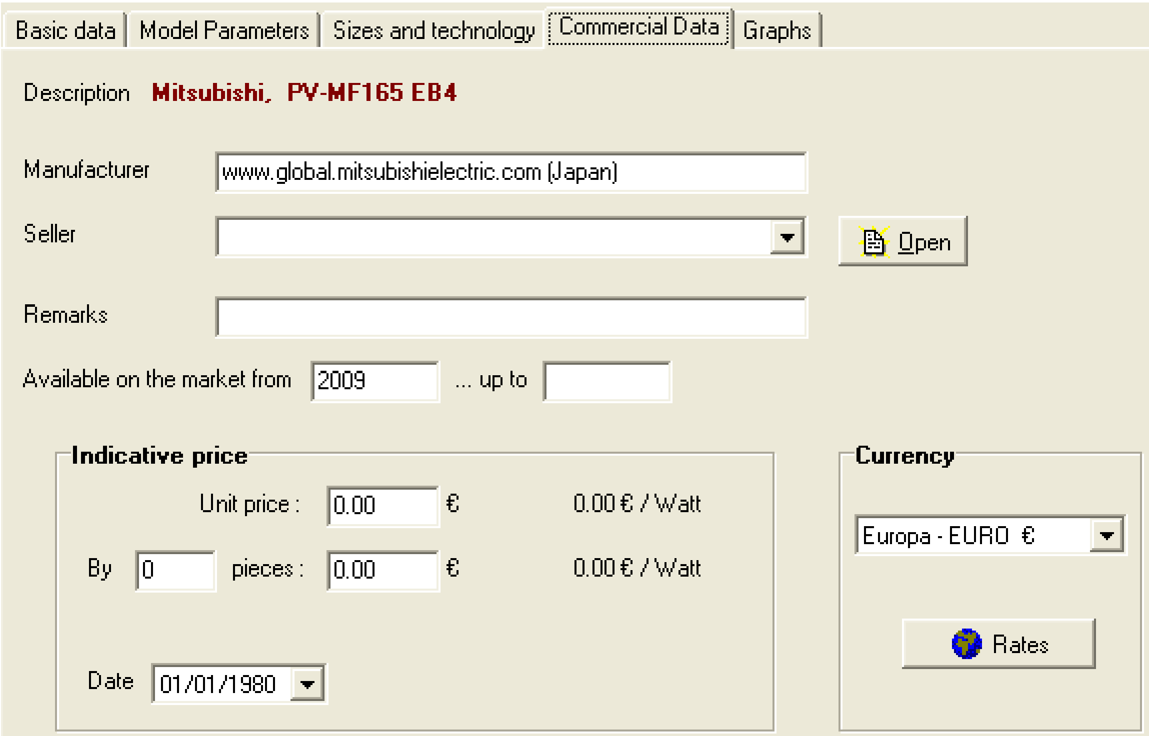
<u>Absorption coefficient for temperature</u>

The thermal behaviour of the field - which strongly influences the electrical performances - is determined by a thermal balance between ambient temperature and cell's heating up due to incident irradiation:

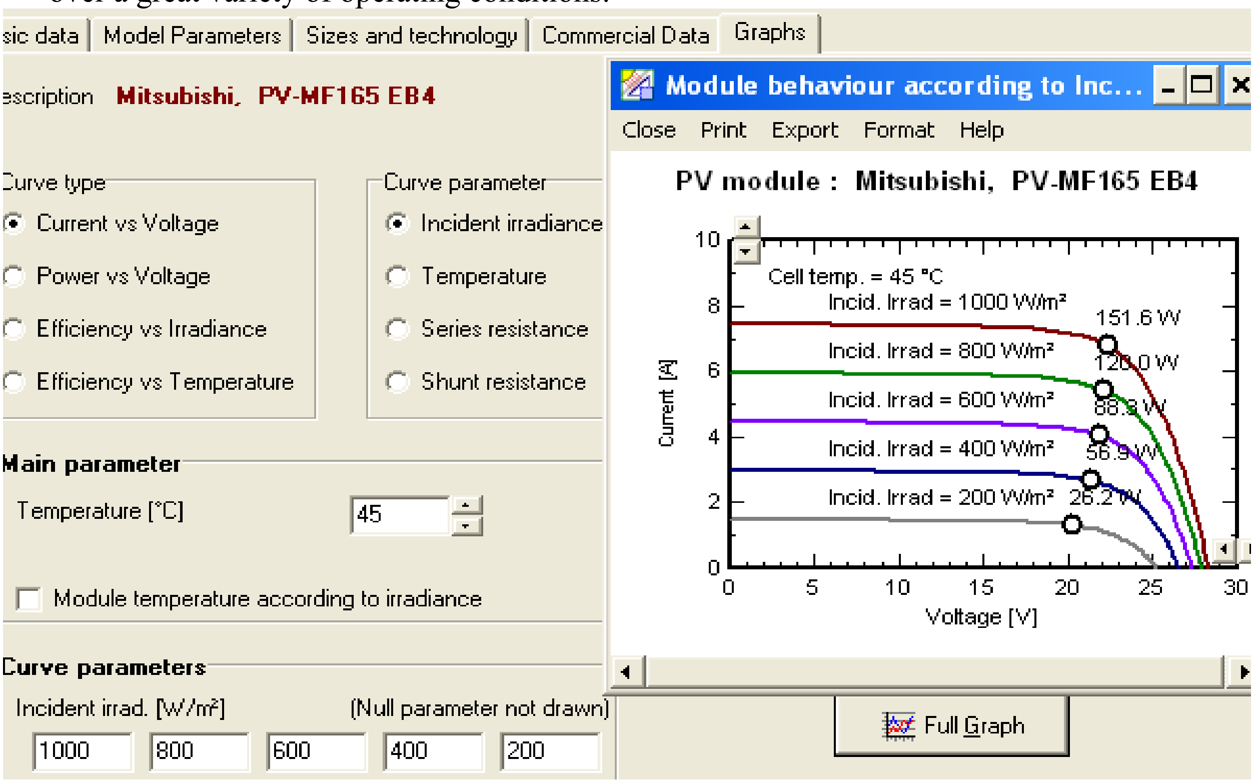
$$\mathbf{k \cdot (Tcell - Tamb) = Alpha \cdot Ginc \cdot (1 - Effic)}$$

where Alpha is the absorption coefficient of solar irradiation, and Effic is the PV efficiency (related to the module area), i.e. the removed energy from the module. The usual value of the Absorption coefficient Alpha is 0.9. Although it is modifiable. When possible, the PV efficiency is calculated according to the operating conditions of the module. Otherwise it is taken as 10%.

2.3.1.4. COMMERCIAL DATA,



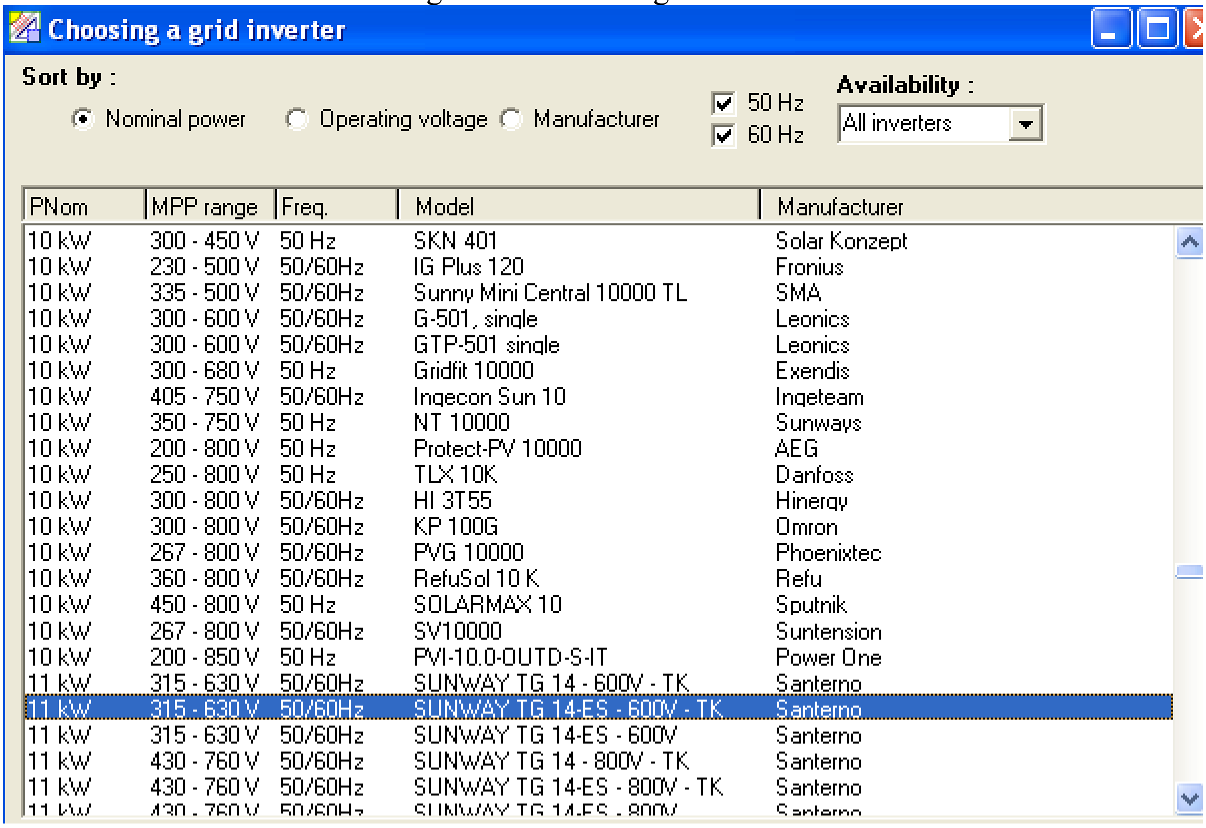
2.3.1.5. GRAPHS, a tool visualising usual and less usual graphs of the PV-model behaviour over a great variety of operating conditions.



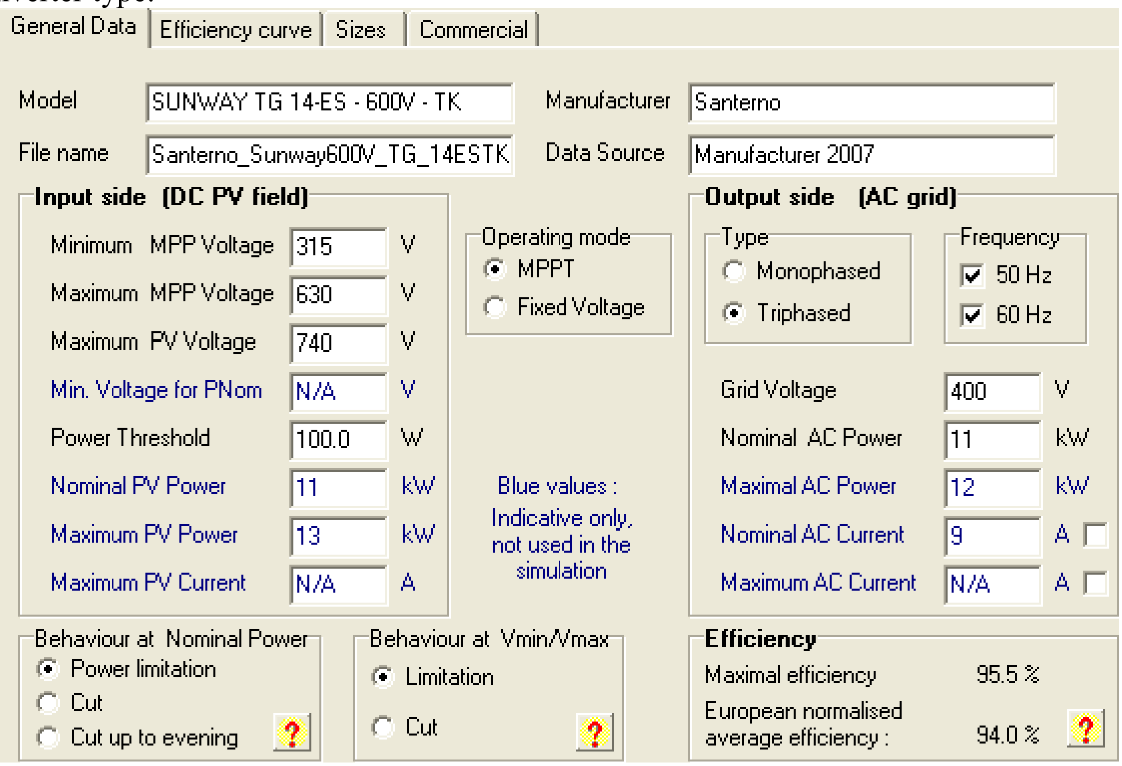
Photovoltaic modules database: data source, adding new modules.
Photovoltaic modules database in Tabular form.

2.3.2. GRID INVERTERS

Grid inverters are defined through a 4-sheet dialog:



2.3.2.1. GENERAL DATA, the identificators and the fundamental properties of a specific inverter type.



Inverter identifiers:

- *Model* and Manufacturer will appear in the inverter choice lists.
- *Data source* usually refers to the efficiency curve measurement source (most often Manufacturer, may be an independent institute or your own measurements).

Input side (DC, PV array)

- *Operating mode*: will always be "maximum power point", i.e. the input electronics is continuously searching for the operating point on the array characteristics, giving the maximum power (I * V).
- *Minimum and Maximum MPP voltage*s is the voltage window in which the inverter is able to search for the MPP. When sizing the array voltage (number of modules in series), this should be taken at operating conditions (around 50°C or 60°C).
- *Maximum voltage* is the absolute allowable maximum under any operating conditions. When sizing the array, it should be compared to 1000 W/m² conditions, at the lower temperature - say 10°C in middle Europe.
- *Minimum voltage for PNom.* Some inverters cannot deliver the full nominal voltage when the input voltage is too low. PVsyst will assume that under this value, the maximum deliverable power will behave as the square of the voltage.
- Power threshold is the minimum input power needed to operate. It is admitted to be the own inverter power operating consumption.
- *Nominal PV power is* the recommended nominal STC power of the PV array.
- *Maximum PV power* is the absolute maximal STC power of the PV array, but its exact definition probably varies from manufacturer to manufacturer.
- *Maximum PV current* admissible at the input of the inverter.
- *Behaviour at nominal power (at AC output),* can be the following:
- Power limitation: during overload , any modern inverter will limit the input power at the nominal value by displacing the operating point on the array I/V curve. This mode gives rise to usually low losses, allowing to oversize the nominal array power by respect to the inverter power.
- Cut : when attaining overload, some old inverter models were simply cutting the PV production by safety.
- Cut up to evening :
- *Behaviour at Vmin/Vmax :*
- Limitation: as above, in modern inverters the operating point stays on the limit voltage when MPP goes outside the window.
- Cut: in some old models the inverter production was stopped when encountering such conditions.

Output side (AC)
- The AC output parameters are not involved in the simulation results nor the system
- performance evaluation, which is only given in terms of Output Power.
- The *mono or triphased mode*: usually Mono for inverters smaller than about 3 kWac, and Tri-phased for greater ones. Most grid distributors impose a limit on the phase unbalance of the order of 3 kW. But of course you can connect an inverter in each phase.
- *The grid frequency* is usually 50 Hz, and 60 Hz for the US zone. Many inverters are designed

for accepting both frequencies, making them useable on all world markets.
- *The Grid Voltage parameter:* But the effective Voltage thresholds specification is not part of the PVsyst parameters.
- *Nominal AC Power:* is the power the inverter can feed continuously.
- *Maximum AC Power* is often specified by the manufacturers, but its signification is not always clear. It is usually a power which may be produced for a short time, until the inverter's temperature becomes too high.
- *Nominal AC current* is usually the current under Nominal power and Nominal grid voltage .
- *Maximum AC current* is also an absolute rating.

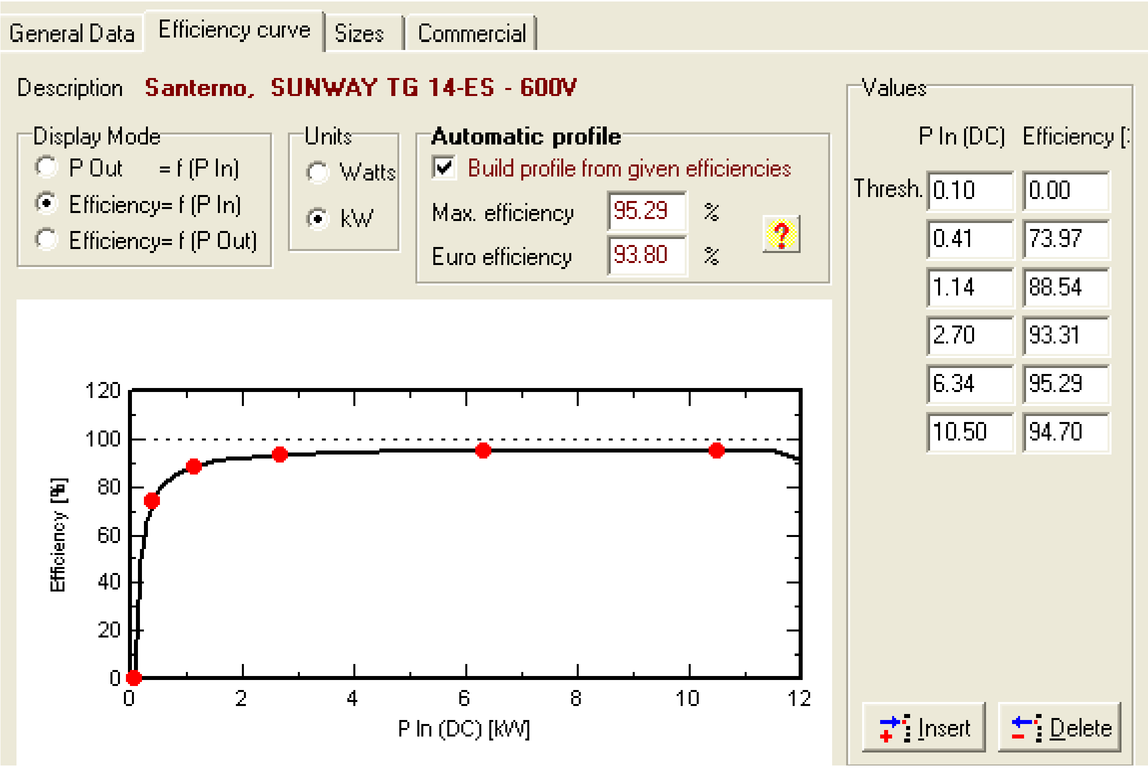
2.3.2.2. EFFICIENCY CURVE, defines the detailed operating efficiency behaviour:

The inverter's efficiency is characterised by a power transfer function during normal operation, depending on the instantaneous power.

This transfer is usually given in terms of efficiency as function either of the input or of the output power. That is, it is represented by a non-linear curve, with a threshold in input power corresponding to the inverter own consumption.
However, it may be more convenient to transform this curve into an input/output power characteristic: the behaviour then becomes practically linear, with a pseudo-straight line cutting the abscissa at the working power threshold. The efficiency elbow is for a great part due to the mathematical transformation of this threshold. Inverter manufacturers try to improve the efficiency at low powers, giving rise to a hardly visible improvement on the beginning of the straight line (when represented as Input/Output graph).

The efficiency curve is rarely given by the manufacturers. For some inverters the database gives the efficiency curve measured by independent institutes.
This programme offers the user the possibility of entering a profile characterised with at most eight points, in any one of these 3 modes (Pout = f(PIn), or Efficiency as a function of Pout or Pin).
Points may be entered by edition or mouse displacement. The particular behaviour which appears at nominal power is characteristic of the chosen overload power behaviour.
<u>Inverter: European Efficiency</u>
The inverter doesn´t operate always at its maximum efficiency.
The European Efficiency is a calculated efficiency, averaged over a power distribution corresponding to middle Europa climate yearly operating conditions.
If we denote by E50 the efficiency at 50% of nominal power, it is defined as:
EuroEfficiency = 0.03·E5 + 0.06·E10 + 0.13·E20 +0.1·E30 + 0.48·E50 +0.2·E100

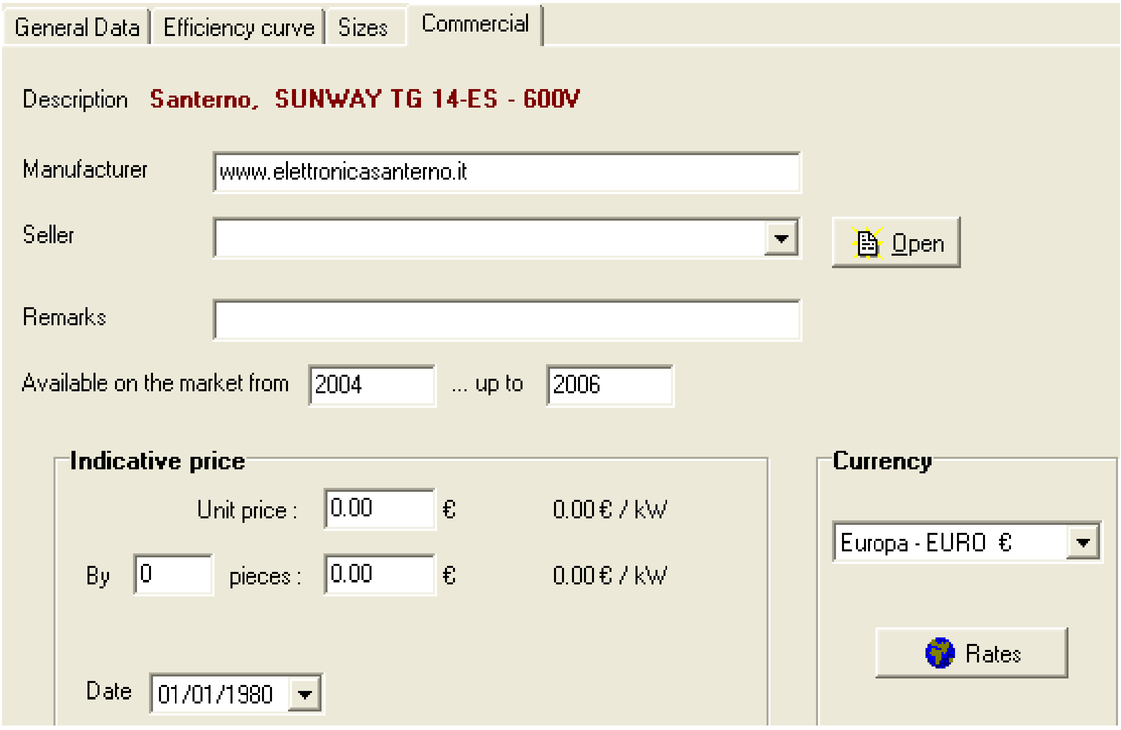
<u>Automatic efficiency curve</u>
More and more often, the manufacturers or databases give the so-called"European Efficiency" which is intented to provide an average efficiency over yearly operating conditions.



2.3.2.3. SIZES : physical sizes and weight, as well as comments about technology,

2.3.2.4. COMMERCIAL DATA,

The grid inverter database includes about 30 inverters ranging from 0.8 to 100 kW.



CHAP III

ECONOMICAL STUDY

CHAP III: ECONOMICAL STUDY

3. FINANCING THE PV STUDY

The installation of a PV systems on surfaces of this building makes possible to combine electrical energy production with other functions of the building structures**.** Grid-connected PV systems represent a reliable solution for electricity supply in buildings; in fact the investment's costs are reduced because no land is required, the support structure is less expensive, and storage batteries aren´t needed. Moreover electricity is generated at the point of use avoiding the transmission and distribution losses.

3.1. FINANCING THE PV STUDY

This chap contains the profitability analysis of the PV bearing in mind the economic and financial situation of Italy in the year of investment (2009). In a context of economic crisis in which financial institutions avoid taking any risk and that very few projects funded by demanding a high return and safe. That´s why It is necessary that this investment of some importance realizes by means of a contract of Leasing, where, a financial institution or investment fund would acquire the PV installation and would penetrate the right of operating of the above mentioned installation to the promoter in exchange for the payment of revenues of lease during a certain term in our project 12 years. At the conclusion of which the financial institution has the option to buy the installation paying a certain price, to return it to the promoter or to renew the contract.

Because of this, we have profited from the Leasing of "Banca Popolare di Vicenza" to stimulate to invest in PV systems with a coverage of up to 100 % of the value of the plant, with the creation since July, 2008, the " Credito Solare ", a new line of lendings without guarantee and the mortgages of up to 100 % of the cost of the acquisition and installation of the plant with attractive tariffs. With a maximum term of 20 years with the aim to balance the percentage of the funding and the resultant benefits of the incentives in the account of energy. The refunds are carried out by a monthly, quarterly or half-yearly frequency.

The Leasing is an option for the companies that don´t rely on the necessary capital of investment to acquire a fixed assets that represents a strong investment of money using it as a mechanism of alternative and innovative financing opposite to a simple bank credit since in this one there is immersed the advantage of the session of use.

3.1.1. INTRODUCTION THE COST

The cost of a PV system is measured in price-per-peak-watt (€/Wp or US$/Wp for example). "Peak Watt" is defined as the power at standard test conditions (solar irradiation 1000 W/m,2 AM of 1.5 and temperature 25°C). Photovoltaic system costs encompass both module and BOS costs. Module costs typically represents only 40-60 % of total PV system costs. Typically the cost of installing a photovoltaic system having a power of 1 kW ranges from 4000 € to 6000 €/kWp (2008).

Approximately about half of this investment would be for the PV modules, and the inverter, PV array support structures, electrical cabling, equipment and installation would account for the rest. Please note that BOS and installation costs can vary significantly. For example: when costs for site preparation, laying a foundation, system design and engineering, permitting, as well as assembly and installation labour are higher, total installation costs are higher also. The life cycle cost (LCC) of a PV system may also include costs for site preparation, system design and engineering, installation labour, permits and operation and maintenance costs. Photovoltaic systems have an anticipated 25-year lifetime. Operation and maintenance costs, ranging between 0,02 to 0,1 cents/kWh. However, these costs can vary significantly, ranging between as low as 0.01 €/kWh to 0.10 €/kWh. The higher reported costs included maintenance costs for generators in remote hybrid PV systems, as well as capital replacement costs due to environmental factors such as extreme temperatures and vandalism. Some studies report that operation and maintenance costs are well correlated to the system size, so 1 % of total hardware costs operation and maintenance costs is expected.

3.1.2. PROFITABILITY ANALYSIS OF THE INSTALLATION

The institutional and financial infrastructure framework covers a wide range of issues that includes the role of government, the legal framework, market barriers, technical capacity, use of local institutions such as non-governmental organisations (NGOs) and the role of the private sector. Market forces and government programmes both play their part in promoting the adoption of PV in developing countries today. However, widespread opinion across a broad range of actors recognises a clear need to strengthen the institutional and financial framework in support of the long-term market development and deployment of PV to global communities.

A detailed cost analysis is performed taking into account initial costs and annual costs involved in the proposed PV project. Thus, this step includes the following cost categories:

- **Initials costs**
- **Feasibility study including:**

– site investigation;

– preliminary design;

– report preparation.

- **Development including:**

– permits and approvals;
– project management;
– travel and accommodation.

- **Engineering including:**

– PV system design;
– structural design;
– electrical design;
– tenders and contracting;
– construction supervision.

- **Renewable energy (RE) equipment including:**

– PV module(s)
– inverter(s);
– transportation.

- **Balance of plant including:**

– module support structure;
– electrical equipment;
– system installation;
– transportation.

- **Miscellaneous including:**

–training;
– contingencies.

- **Annual costs**

– Operation and maintenance including:
– property taxes/insurance;
– others;
– contingencies.

- **Financial summary”** includes the following main categories:
- – financial parameters;
- – energy balance;
- – project costs and savings;
- – financial feasibility;
- – yearly cash flow.

A number of different economic and financial feasibility indices are calculated such as the year-to-positive cash flow, internal rate of return (IRR), return of investment (ROI), net present value (NPV) and the results of the installed small scale PV power plant are shown then.

3.1.3. ITALIAN SUPPORT PROGRAM

The Ministerial Decree dated February 19th 2007 defined criteria that provide incentives for electricity generation by photovoltaic solar plants.

This tariff varies as a function of plant capacity (from 1 to 3 kWp, from 3 to 20 kWp and more than 20 kWp) according to the typology of photovoltaic installation (power plants that are integrated or not in the buildings and ground based PV systems).

The incentive is valid for a period of 20 years and varies from 0.49 €/kWh, to 0.36 €/kWh, for nonintegrated and ground based PV systems, more than 20 kWp installed in 2007 and in 2008:

INCENTIVING TARIFFS 2008			
POWER CLASS (kWp)	**Not integrated (€/kWh)**	**Partially integrated (€/kWh)**	**Integrated (€/kWh)**
1 kWp ≤ P ≤ 3 kWp	**0,40**	**0,44**	**0,49**
3 kWp < P ≤ 20 kWp	**0,38**	**0,42**	**0,46**
P > 20 kWp	**0,36**	**0,40**	**0,44**

For the facilities entered exercise the period intercurrente between January 1, 2009 and December 31, 2010, the tariffs are reduced of 2 % each of the years of following calendar 2008.

The following board teaches this tariffs:

INCENTIVING TARIFFS 2009			
POWER CLASS (kWp)	**Not integrated (€/kWh)**	**Partially integrated (€/kWh)**	**Integrated (€/kWh)**
1 kWp ≤ P ≤ 3 kWp	**0,392**	**0,431**	**0,480**
3 kWp < P ≤ 20 kWp	**0,372**	**0,412**	**0,451**
P > 20 kWp	**0,353**	**0,392**	**0,431**

The incentive is distributed by the Manager of the Electrical Services: GSE S.p.a.

3.2. DATES, INPUT AND OUTPUT

3.2.1. ECONOMIC DATES

The present document takes as year of his possible execution and I develop the fiscal year 2009. Of the same way the average premium is established as reference by KW produced in special regime with technology photovoltaic and regulated by the **"Conto Energia" (DM 19/2/2007)** between the first quarters of 2009, being this of 0,392 €/KWh.

Of this form a credit will be obtained to 20 years, with a year of lack, in which one will pay the proportional part to the financial institution or group of investment. In the above mentioned contract there would be negotiated the interest of applicable exit. To provide a safety coefficient to the development of the project, saying it is fixed in 6,3 % (Euribor of the first year + the differential one).

Then a tax relief is fixed on 5 % in 2010, one 4 % in 2011 and one 3 % in 2012. From then of the above mentioned year no type of tax relief would exist.

The specific production estimated for the fixed installation in Pavia and with the technology detailed in the first chap is = 420.550 kWh year / 39,6 kWp installated = 1.065 KWh/KWp after a year. Also there is applied a factor of losses of estimated power in 0,08 % after a ogni year.

The total price according to budget of the PV studied installation is: 166.906 € that is divided to 39, 6 kWp installated we have obtained the unitary price of 4,20 €/Wp. All the installed equipments will have to present a guarantee of 10 years, for what the repairs realized during this period will go at the expense of the manufacturer.

In the following table “Economic Date” there appears the totality of the information from which the profitability of the project has been studied:

1	PHOTOVOLTAIC INSTALLATION DATA	INPUT DATA
1	Year of starting up (or signature of the leasing)	2009
2	Power of the installation (Wp installed)	39.600
3	Unitary Price (€uros/Wp)	4,20 €
4	Paid for own means	70,00%
5	Years of credit (Only those of capital payment. Already one bears in mind of lack)	20
6	Interest rate of exit (It´s in the habit of being Euribor 1 year + differentially - an average Predicts to 25 years)	6,30%
7	Environmental Tax exemption 10 years (Law: 5 % in 2010, 4 % in 2011, 3% in 2012. From then 0 %)	5,00%
8	Specific Estimated productionfor fixed installation specific (kWh year / kWp installed)	1065
9	Percentage increase of production for using follower of one or two axes	0
10	Losses of estimated production	0,08%
11	Price of the regular tariff (That one who is in effect in every moment in €uros / kWh))	0,392
12	Changeable Expenses on production (Percentage on income that it covers maintenance costs, etc.).)	3,00%
13	Years without the previous changeable expenses for finding the installation in guarantee period.	10
14	Rent of areas, assurance, IBI, maintenance and other overheads.	120 €
15	Consumer price index, CPIe, stimated as average of 25 years valid for income and expenses.	3,60%
16	Discount rate (Type of long-term products like " Bonds of the State " to a term similar to 25 years)	5,50%
17	Taxes, N.R.T. (National Rental Tax= Personal Income Tax) (Number that one thinks that it is going to be paid)	19,00%

3.2.2. INVESTMENT

Later one shows all the information relating to the foreseen investment, from which it is necessary to distinguish that the project presents a N.P.V. of 100.098 € and one I.R.R. of 12,03 %, estimating 20 years those of return of the investment.

Also one presents the totality of expenses and income, as well as the solvent interests and the total realized tax relief.

3.2.2.1. V. A.T.

An economic analysis shows that, with actual prices of PV standard panels, a PV plant in Italy requires a maximum time of about 16-17 years to pay-back starting investment; depending on the location, on the kind and quality of panel and on the kind of assembling if fix or sun following, the pay-back time could be sensitively decreased. Not negligible role is played in any case by VAT (Italian IVA), above all for private Customers. In Italy a VAT rate 10% (already reduced referring VAT "normal" rate that amounts to 20%) is added to any energy related product, as energy sold by Energy Supplier to private customers, as PV panels and PV installations.

If VAT represents not a "problem" for commercial companies, because there is a compensation between VAT amounts in and out, it represents and additional cost for private Customers. Energy supplied by PV panel contributes in fact to reduce VAT amount on energy bill, as Customer reduces energy consumption by the net, by self producing energy. But private Customer has to mind to VAT added also when he decides to buy PV panels and installation. This aspect should increase pay-back time, even if we consider VAT reduction on energy bill.

Same "problems" are for Public Organizations such as Municipalities, Provinces, etc. that in Italy don't have any VAT compensation.

2	INFORMATION EXPECTED FROM THE INVESTMENT		AUTOMATIC
1	Total cost of the installation without V.A.T		166.320 €
2	V.A.T. of the installation who would pay the bank in case of leasing		4.990 €
3	V.A.T. of the installation corresponding to the buyer on the part of counted		11.642 €
4	Total Cost of the installation(V.A.T. Included)		182.952 €
5	Paid for own means	70,00%	116.424 €
6	Whole to financing	30,00%	49.896 €
7	Annual interesting quota more recovery time		4.457 €
8	Monthly Quota included recovery time		371 €
9	Interests paid during the life of the credit.		42.381 €
10	Average annual Expenses		2.422 €
11	Average monthly Expenses.		202 €
12	Specific Expected annual Production in kWh x year / kWp installed.		1.065
13	Total foreseen annual Production in kWh x year.		42.174
14	Income for average annual production before taxes		25.865 €
15	Income for production monthly average before taxes.		2.155 €
16	Profitability happens on total investment before taxes		10,10%
17	Profitability happens on investment of own means before taxes.		14,42%
18	Percentage that remains free after paying taxes. .		81,00%
19	N.P.V. Net present value.		100.098 €
20	N.P.V. Average annual on investment of own means.		3,44%
21	Years of return of the investment		12
22	Discount rate (Weighted average)		5,74%
23	Environmental Tax relief (according to law 35 % liquid quota)		6.917 €
24	IRR (internal return rate)		12,03%

3.2.3. OPERATING EXPENSES

In the following table there are detailed all the operating expenses relating to the PV installation during the whole useful life of the same one (25 years).

Between the expenses one finds the "Leasing" (Present balance of the lending and the " Principal Leasing " (annual repayment of the lending), the annual interests of the lending, the changeable expenses (principally due to the maintenance of the plant), detailed previously.

3	OPERATING EXPENSES						
MOMENT	YEAR	LEASING	PRINCIPAL LEASING	INTEREST	CHANGEABLE EXPENSES PROCTION	CHANGEABLE EXPENSES	TOTAL EXPENSES
Unit		€	€	€	€	€	€
0	2009	49.896		3.143			3.143
1	2010	49.896	1.313	3.143	0	120	3.263
2	2011	48.583	1.396	3.061	0	124	3.185
3	2012	47.187	1.484	2.973	0	129	3.102
4	2013	45.703	1.577	2.879	0	133	3.013
5	2014	44.125	1.677	2.780	0	138	2.918
6	2015	42.449	1.782	2.674	0	143	2.817
7	2016	40.666	1.895	2.562	0	148	2.710
8	2017	38.771	2.014	2.443	0	154	2.596
9	2018	36.757	2.141	2.316	0	159	2.475
10	2019	34.616	2.276	2.181	0	165	2.346
11	2020	32.340	2.419	2.037	711	171	2.919
12	2021	29.921	2.572	1.885	734	177	2.796
13	2022	27.350	2.734	1.723	757	183	2.664
14	2023	24.616	2.906	1.551	782	190	2.522
15	2024	21.710	3.089	1.368	807	197	2.371
16	2025	18.621	3.284	1.173	833	204	2.210
17	2026	15.337	3.490	966	859	211	2.037
18	2027	11.847	3.710	746	887	219	1.852
19	2028	8.137	3.944	513	916	227	1.655
20	2029	4.193	4.193	264	945	235	1.444
21	2030	0	0	0	975	243	1.219
22	2031	0	0	0	1.007	252	1.259
23	2032	0	0	0	1.039	261	1.300
24	2033	0	0	0	1.073	271	1.343
25	2034	0	0	0	1.107	280	1.387
		TOTAL	49.896	42.381	13.430	4.737	60.548

3.2.4. INCOMES

In this paragraph all the economic inputs are registered in the plant relating to income by the development of the project.The discount is born in mind to the total production per year of 0,08 % by losses by aging of the equipments.

In addition a coefficient applies reducer to itself to the update of the applicable CPI: Consumer Prices Index as increase of tariff (according to “Regulation n.2602/2000 discounts”).

Finally this table appears where there is gathered all the economic income that there provides in our PV installation:

4		FORECAST INCOME IN THE INSTALLATION						
MOMENT	YEAR	LOSS STIMATED	LOSS ACUMULATED	PRODUCTION ESTIMATED	COEFFICIENT REDUCER. CONSUMER PRICES INDEX (CPI)	CPI REDUCED	PRICE kWh.	INCOME
Unit		%	%	Kwh.		%	€	€
0	2009						0,392000	0
1	2010			42.174	0,19%	3,41%	0,405367	17.096
2	2011	0,08%	-0,08%	42.140	0,19%	3,41%	0,419190	17.665
3	2012	0,08%	-0,16%	42.107	0,19%	3,41%	0,433485	18.253
4	2013	0,08%	-0,24%	42.073	0,19%	3,41%	0,448266	18.860
5	2014	0,08%	-0,32%	42.039	0,19%	3,41%	0,463552	19.487
6	2015	0,08%	-0,40%	42.005	0,19%	3,41%	0,479359	20.136
7	2016	0,08%	-0,48%	41.972	0,19%	3,41%	0,495706	20.806
8	2017	0,08%	-0,56%	41.938	0,19%	3,41%	0,512609	21.498
9	2018	0,08%	-0,64%	41.904	0,19%	3,41%	0,530089	22.213
10	2019	0,08%	-0,72%	41.870	0,19%	3,41%	0,548165	22.952
11	2020	0,08%	-0,80%	41.837	0,30%	3,30%	0,566255	23.690
12	2021	0,08%	-0,88%	41.803	0,30%	3,30%	0,584941	24.452
13	2022	0,08%	-0,96%	41.769	0,30%	3,30%	0,604244	25.239
14	2023	0,08%	-1,04%	41.735	0,30%	3,30%	0,624184	26.051
15	2024	0,08%	-1,12%	41.702	0,30%	3,30%	0,644782	26.888
16	2025	0,08%	-1,20%	41.668	0,30%	3,30%	0,666060	27.753
17	2026	0,08%	-1,28%	41.634	0,30%	3,30%	0,688040	28.646
18	2027	0,08%	-1,36%	41.600	0,30%	3,30%	0,710745	29.567
19	2028	0,08%	-1,44%	41.567	0,30%	3,30%	0,734200	30.518
20	2029	0,08%	-1,52%	41.533	0,30%	3,30%	0,758429	31.500
21	2030	0,08%	-1,60%	41.499	0,30%	3,30%	0,783457	32.513
22	2031	0,08%	-1,68%	41.465	0,30%	3,30%	0,809311	33.558
23	2032	0,08%	-1,76%	41.432	0,30%	3,30%	0,836018	34.638
24	2033	0,08%	-1,84%	41.398	0,30%	3,30%	0,863607	35.752
25	2034	0,08%	-1,92%	41.364	0,30%	3,30%	0,892106	36.901
			TOTAL	1.044.228				646.631

2.5. PROFIT AND LOSS ACCOUNT

The following table shows the profit and loss account of photovoltaic exploitation during the 25 year life, detailing income, expenses, taxes, deductions, benefits and profitability.

5	PROFIT AND LOSS ACCOUNT						
MOM.	YEAR	RECOVERY	OPERATING COSTS	TOTAL EXPENSES	TOTAL INCOMES	PROFITS	PROFITABILITY BEFORE TAXES
Unit		€	€	€	€	€	%
0	2009		3.143	3.143	-	-3.143	-1,89%
1	2010	6.653	3.263	9.916	17.096	7.180	4,32%
2	2011	6.653	3.185	9.838	17.665	7.827	4,71%
3	2012	6.653	3.102	9.754	18.253	8.498	5,11%
4	2013	6.653	3.013	9.666	18.860	9.194	5,53%
5	2014	6.653	2.918	9.571	19.487	9.916	5,96%
6	2015	6.653	2.817	9.470	20.136	10.665	6,41%
7	2016	6.653	2.710	9.363	20.806	11.442	6,88%
8	2017	6.653	2.596	9.249	21.498	12.249	7,36%
9	2018	6.653	2.475	9.128	22.213	13.085	7,87%
10	2019	6.653	2.346	8.999	22.952	13.953	8,39%
11	2020	6.653	2.919	9.572	23.690	14.118	8,49%
12	2021	6.653	2.796	9.448	24.452	15.004	9,02%
13	2022	6.653	2.664	9.316	25.239	15.922	9,57%
14	2023	6.653	2.522	9.175	26.051	16.875	10,15%
15	2024	6.653	2.371	9.024	26.888	17.864	10,74%
16	2025	6.653	2.210	8.862	27.753	18.891	11,36%
17	2026	6.653	2.037	8.690	28.646	19.956	12,00%
18	2027	6.653	1.852	8.505	29.567	21.062	12,66%
19	2028	6.653	1.655	8.308	30.518	22.210	13,35%
20	2029	6.653	1.444	8.097	31.500	23.403	14,07%
21	2030	6.653	1.219	7.872	32.513	24.641	14,82%
22	2031	6.653	1.259	7.912	33.558	25.647	15,42%
23	2032	6.653	1.300	7.953	34.638	26.684	16,04%
24	2033	6.653	1.343	7.996	35.752	27.756	16,69%
25	2034	6.653	1.387	8.040	36.901	28.861	17,35%
TOTAL		166.320	60.548	226.868	646.631	419.763	10,10%

5	PROFIT AND LOSS ACCOUNT						
MOM.	YEAR	NET INCOME TAX PAYABLE	DEDUCTION ENVIRONMENT	DEDUCTION ENVIRONMENT	QUOTA INCOME TO PAY	PROFITS AFTER TAXES	FINANCIAL PROFITABILITY
Unit		€		€	€	€	%
0	2009	-597	8.316	8.316	-597	-2.546	-2,70%
1	2010	1.364	477	477	887	6.293	6,17%
2	2011	1.487	998	520	967	6.860	6,72%
3	2012	1.615	1.563	565	1.050	7.449	7,30%
4	2013	1.747	2.174	611	1.135	8.059	7,90%
5	2014	1.884	2.834	659	1.225	8.692	8,52%
6	2015	2.026	3.543	709	1.317	9.348	9,16%
7	2016	2.174	4.304	761	1.413	10.029	9,83%
8	2017	2.327	5.119	815	1.513	10.736	10,52%
9	2018	2.486	5.989	870	1.616	11.469	11,24%
10	2019	2.651	6.917	928	1.723	12.230	11,98%
11	2020	2.682			2.682	11.436	12,13%
12	2021	2.851			2.851	12.153	12,89%
13	2022	3.025			3.025	12.897	13,68%
14	2023	3.206			3.206	13.669	14,49%
15	2024	3.394			3.394	14.470	15,34%
16	2025	3.589			3.589	15.302	16,23%
17	2026	3.792			3.792	16.165	17,14%
18	2027	4.002			4.002	17.060	18,09%
19	2028	4.220			4.220	17.991	19,08%
20	2029	4.447			4.447	18.956	20,10%
21	2030	4.682			4.682	19.959	21,17%
22	2031	4.873			4.873	20.774	22,03%
23	2032	5.070			5.070	21.614	22,92%
24	2033	5.274			5.274	22.482	23,84%
25	2034	5.484			5.484	23.377	24,79%
TOTAL		79.755		6.917	72.838	346.924	14,42%

Where:

Net Income Tay Payable: is a type of account in the current liabilities section of a company's balance sheet. This account is comprised of taxes that must be paid to the government within one year. Income tax payable is calculated according to the prevailing tax law in the company's home country. This account is usually identified in the balance sheet when the company has received its tax bill but has put off paying it for the time being.

2.6. CASH FLOW AND PAYBACK

Finally, it details the cash flow presented in the project analyzed 25 years, presenting input and output, annual cash flow update.

Also calculated the NPV (Net Present Value of investment, ie the constant dollar value given year zero flows in and out) and IRR (Internal Rate of Return at the end of the investment, which indicates the discount rate required for the NPV of the investment is zero, ie the value of the outputs and inputs analyzed equating).

We conclude that in **12** years would have repaid the entire capital provided their own resources to the implementation and operation of the project.

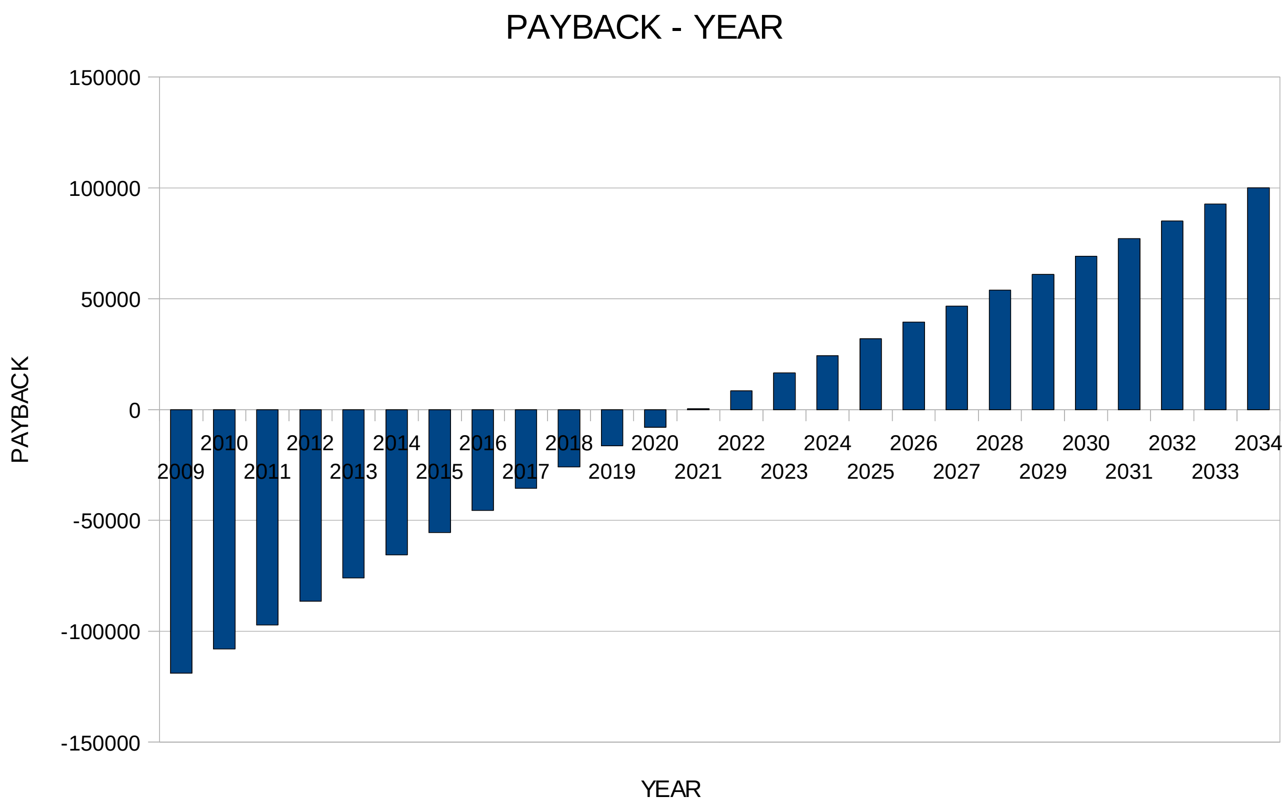
The following table shows the cash flow from operating the PV installation:

6		CASH FLOW									
MOM	YEAR	PRICIPAL LEASING	INTEREST	OPERATING COSTS	TAXES	TOTAL EXPENDITURES	TOTAL INCOMES	CASH FLOW	CASH FLOW UPDATED	PAYBACK RETORNO INVERSION	I.R.R. Up to year 'x'
Unit		€	€	€	€	€	€	€	€	€	%
0	2009	-	3.143	-	-597	2.546	-	-118.970	-118.970	-118.970	
1	2010	1.313	3.143	120	887	5.463	17.096	11.633	11.001	-107.969	
2	2011	1.396	3.061	124	967	5.548	17.665	12.117	10.837	-97.132	
3	2012	1.484	2.973	129	1.050	5.635	18.253	12.618	10.672	-86.460	
4	2013	1.577	2.879	133	1.135	5.726	18.860	13.134	10.506	-75.953	-27,34%
5	2014	1.677	2.780	138	1.225	5.820	19.487	13.668	10.339	-65.614	-17,60%
6	2015	1.782	2.674	143	1.317	5.917	20.136	14.219	10.172	-55.442	-10,75%
7	2016	1.895	2.562	148	1.413	6.018	20.806	14.787	10.005	-45.437	-5,79%
8	2017	2.014	2.443	154	1.513	6.123	21.498	15.375	9.838	-35.599	-2,10%
9	2018	2.141	2.316	159	1.616	6.232	22.213	15.981	9.670	-25.929	0,72%
10	2019	2.276	2.181	165	1.723	6.345	22.952	16.607	9.504	-16.425	2,91%
11	2020	2.419	2.037	882	2.682	8.021	23.690	15.669	8.480	-7.944	4,50%
12	2021	2.572	1.885	911	2.851	8.218	24.452	16.234	8.309	365	5,79%
13	2022	2.734	1.723	941	3.025	8.423	25.239	16.816	8.140	8.505	6,85%
14	2023	2.906	1.551	972	3.206	8.635	26.051	17.416	7.973	16.477	7,73%
15	2024	3.089	1.368	1.004	3.394	8.854	26.888	18.034	7.807	24.285	8,47%
16	2025	3.284	1.173	1.037	3.589	9.083	27.753	18.671	7.644	31.929	9,09%
17	2026	3.490	966	1.071	3.792	9.319	28.646	19.327	7.483	39.412	9,61%
18	2027	3.710	746	1.106	4.002	9.564	29.567	20.003	7.325	46.737	10,05%
19	2028	3.944	513	1.142	4.220	9.819	30.518	20.699	7.168	53.905	10,43%
20	2029	4.193	264	1.180	4.447	10.083	31.500	21.417	7.014	60.919	10,76%
21	2030	-	-	1.219	4.682	5.901	32.513	26.612	8.242	69.161	11,10%
22	2031	-	-	1.259	4.873	6.132	33.558	27.427	8.034	77.195	11,39%
23	2032	-	-	1.300	5.070	6.370	34.638	28.267	7.830	85.025	11,64%
24	2033	-	-	1.343	5.274	6.617	35.752	29.135	7.633	92.658	11,85%
25	2034	-	-	1.387	5.484	6.871	36.901	30.030	7.440	100.098	12,03%
TOTAL		49.896	42.381	18.167	72.838	183.282	646.631	346.924	100.098		
				V.A.N. / 25 years / Investment M.P.			3,44%	V.A.N.		100.098 €	
								T.I.R. (to 25 years)		12,03%	
								PAY BACK (In years)		12	

3.2.6.1. PAY BACK GROUND

Simple payback is a measure of economic feasibility that is interpreted to be the number of years an investment takes to pay for itself. It is typically defined as the net cost divided by the first year savings. That is, the simple payback equals the net cost to the user after all incentives (e.g., tax credit, buy-downs, etc.), divided by the first year savings (chiefly reduced electric bills minus expenses).

Simple Payback = Net Cost/First Year Savings



3.2.6.2. CASH FLOW

However straightforward and compelling it may be, the simple payback measure may not capture all financial benefits available to prospective buyers. These benefits include:

- The possibility of borrowing to pay for the system through a loan (e.g., home equity loan or a mortgage)
- The fact that loan interests may be tax-deductible
- The existence of loan interest buy-down incentives available in some states
- Cash flows that vary substantially from year to year

A pragmatic way to account for all these factors is to look at a system's cash flow over its lifetime. Cash flow represents the periodic income, or out-of-pocket expense, associated with ownership of the system. For any particular year, it may be expressed as

Cash Flow = Energy Value – O&M Cost – Loan Payment + Tax Savings (from interest payment or depreciation)

CHAP IV

ENVIRONMENTAL STUDY

CHAP. IV. ENVIRONMENTAL STUDY

4. ENVIRONMENTAL STUDY

4.1. INTRODUTION

In recent years, energy systems have been undergoing a development trend characterised by privatization of the most important energy sectors (electricity and natural gas) that has turned former monopolies into free-market competitors. Furthermore, community awareness of environmental impact caused by large conventional power plants is growing, together with a greater interest in distributed-generation technologies based upon renewable energy sources (RES) and cogeneration. In this context, renewable energy technologies are emerging as potentially strong competitors for more widespread use.

Despite the remarkable progress attained over the past decades, RES have not yet been fully integrated into the power sector. Some RES-technologies have already achieved a significant market share. The industry is now quite mature, although far from having developed its global potential.

Solar energy forms one of the cornerstones of clean alternate power solutions, and with the difficulties of fossil fuels growing larger by the day, may represent a viable solution to the world's energy problems. Its environmental impact constitutes one of its primary selling points, and the more effectively it can function, the better its chances of supplanting fossil fuels as our main source of energy. Though largely positive, the environmental impact of solar energy can be subtle and its overall effect should be carefully considered as our efforts to explore its potential move forward.

Solar energy systems (photovoltaics, solar thermal, solar power) provide significant environmental benefits in comparison to the conventional energy sources, thus contributing, to the sustainable development of human activities. Sometimes however, their wide scale deployment has to face potential negative environmental implications. These potential problems seem to be a strong barrier for a further dissemination of these systems in some consumers.

To cope with these problems this paper presents an overview of an Environmental Impact Assessment. We assess the potential environmental intrusions in order to ameliorate them with new technological innovations and good practices in the future power systems. The analysis provides the potential burdens to the environment, which include noise and visual intrusion, greenhouse gas emissions, water and soil pollution, energy consumption, labour accidents, impact on archaeological sites or on sensitive ecosystems, negative and positive socio-economic effects.

Solar Energy Internation indicates that there are many other benefits to consider when choosing photovoltaic technology:

- **Reliability**: Even under the harshest of conditions, PV systems maintain electrical power supply. In comparison, conventional technologies often fail to supply power in the most critical of times.

- **Durability**: Most PV modules available today show no degradation after ten years of use. With the constant advancement in solar energy systems, it is likely that future modules will not show signs of degradation for up to 25 years or more. PV modules produce more energy in their lifetime than it takes to produce them.

- **Low Maintenance Cost**: PV systems do not require frequent inspection or maintenance. Transporting supplies may get costly, but these costs are usually less than with conventional systems.

- **No Fuel Cost**: Since there is no fuel source, there is no required exspenditure on the purchasing, storing, or transporting fuel.
- **Reduced Sound Pollution**: PV systems operate silently and with minimal movement.
- **PV Modularity:** Unlike conventional systems, modules may be added to photovoltaic systems to increase available power.
- **Safety**: PV systems do not require the use of combustible fuels, and are very safe when properly designed and installed.
- **Independence**: PV systems may operate independent of grid systems. This is a large advantage for rural communities in nations lacking basic infrastructure.
- **Electrical Grid Decentralization**: Small-scale decentralized power stations reduce the possibility of power outages, which are often frequent on the electric grid.
- **High Altitude Performance**: When using solar energy, power output is optimized at higher elevations. This is very advantageous for high altitude, isolated communities where diesel generators must be de-rated due to the loss in efficiency and power output.

4.1.1. ADVANTAGES OF PHOTOVOLTAICS

- Mechanically simple, there are no moving parts in a PV cell;
- Production of DC current means battery storage is simple;
- PV cells make no noise and give off no exhaust;
- Allow the use of electricity in remote areas where it would be expensive or impossible to run power lines.

4.1.2. DISADVANTAGES OF PHOTOVOLTAICS.

- PV power is currently more expensive than power from utilities;
- Light is required to generate electricity so night time and cloudy days do not produce power;
- To use AC appliances inverters must be used;
- Battery storage means additional maintenance and replacement;
- Some of the materials used in PV production are toxic.

4.2. OBJETIVE

4.2.1. ENVIRONMENTAL IMPACTS OF SETs

Solar Energy Technologies (SETs) provide significant environmental benefits when compared to the conventional energy sources, contributing to the sustainable development. The use of SETs has positive environmental implications such as:

· reduction of the CO_2 emissions;

· improvement of the quality of water supplies;

· reclamation of degraded land;

· reduction of the number of the required power transmission lines.

- **Stages of Life Cycle Analysis and Assessment for Solar Energy Systems.**

From the socio-economic viewpoint the benefits of the use of SETs include:

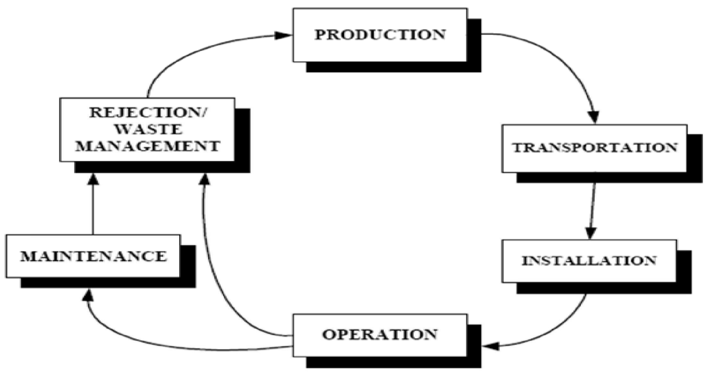
· reduction of the national dependency on fuel imports;

· diversification and security of energy supply;

· provision of significant job opportunities and working positions;

· support of the energy market deregulation;

· acceleration of the rural electrification in developing countries.



The potential environmental burdens of SETs depend on the size and nature of the project and are frequently site specific. These burdens are usually associated with loss of amenity (e.g. visual impact or noise) and the impacts can be minimized by:

· appropriate siting, which involves careful evaluation of alternative locations and estimation of expected impact;

· EIA studies, which propose appropriate mitigation measures;

· the use of the best available technologies/techniques;

· evaluating the local, regional and global benefit and cost;

· engaging the public and relevant organizations in the early stages of planning, in order to ensure public acceptance.

4.3. PV POWER GENERATION

4.3.1 ENVIRONMENTAL IMPACTS

- **Environmental benefits**: Significant emission reductions can be accomplished through PV electricity production since PVs do not generate noise or chemical pollutants during their normal operation. Besides, PV cells help the increase of soil humidity and improve flora formation in dry/arid areas.
- **Social impacts:** Some direct benefits are related to lighting for domestic and community activities and mainly to the opportunity to suburban and borderland's habitants to have access to computers, lighting, radio and phone. Therefore PVe improves the quality of life and reduces migration. During installation and maintenance full- and part-time jobs creation improves local microeconomics and drives to poverty alleviation.
- **Land use:** The impact of land use on natural ecosystems is depended on specific factors such as the topography, the area and the type of the land covered by the system, the distance from areas of natural beauty or sensitive ecosystems and the biodiversity. The impacts and the modification on the landscape are likely to come up during construction stage, by activities such as earth movements and by transport movements. Also an application of a system in once-cultivable land is possible to reserve soil productive areas. Thus the siting in arid areas is recommended.
- **Visual impact:** Visual intrusion is highly dependent on the frame design and the surroundings of the PVs. It is obvious that, for a system near an area of natural beauty, the visual impact will be significantly high.
- **Effect on building:** PV is a viable technology in an urban environment, to replace the existing building's cladding materials. Also, PV panels can be directly used into the façade of a building instead of mirrors.
- **Accidental releases and occupational health:** Emissions into soil and groundwater may be caused by inadequate storage of materials. In large-scale plants a release of these hazardous materials is likely to occur as a result of abnormal plant operations, damaged modules or fire and therefore to pose a small risk to public and occupational health. The increased potential danger of electrocution from the direct current produced by systems, needs to be taken into account especially by untrained users.
- **Air pollution:** The emissions associated with transport of the modules are minor in comparison to those associated with manufacture. Transport emissions were still only 1% of manufacturing related emissions.
- **Depletion of natural sources and energy consumption:** The production of current generation poly- and mono-crystalline modules is rather energy intensive. Other indirect impacts include the requirement of large quantities of bulk materials and small quantities of scarce (In/Te/Ga) and/or toxic (Cd) materials. Options for energy demand reduction must always be considered along with the assessment of PV applications.
- **Waste management**: In the case of stand alone systems the effects on health of chemical substances included in the batteries should also be studied. Moreover a large amount of energy and raw materials is required for their production. A battery-recycling scheme can assist. As it usually goes for construction activities, there will be little noise during operation of electrical equipment.

4.3.2 TECHNIQUES TO MITIGATE THE ENVIRONMENTAL IMPACTS

Almost all the negative environmental impacts can be faced:

- PVs can be used in isolated areas, avoiding ecologically sensitive areas or archeological sites.
- The integration in large commercial buildings (facades, roofs) it is also recommended as well as the use as sound isolation in highways or nearby hospitals, on condition of proper siting and frequent maintenance
- Careful system design and production of cells in variable shapes, which can be easily integrated in buildings as architectural elements and replace mirrors or metallic areas used to decorate modern buildings. Furthermore the PV use as a cladding material for commercial buildings is showing their architectural possibilities. Referring to construction activities, site restoration is needed to alleviate visual impacts. Color can be used to assemble the PV modules in large-scale systems.
- Occupational accidents can be averted by good working practices and by the use protective sunglasses and clothing during construction, maintenance and decommission stage.
- Integrated PVe schemes help to regenerate rural areas.

4.4. ENVIRONMENTAL EFFECTS OF SOLAR ENERGY

Solar energy forms one of the cornerstones of clean alternate power solutions, and with the difficulties of fossil fuels growing larger by the day, may represent a viable solution to the world's energy problems. Its environmental impact constitutes one of its primary selling points, and the more effectively it can function, the better its chances of supplanting fossil fuels as our main source of energy. Though largely positive, the environmental impact of solar energy can be subtle and its overall effect should be carefully considered as our efforts to explore its potential move forward.

To know the enviromental impact, we are use the software Solarius - Pv that inside the paragraph of economic analysis allows to obtain the incentive tariff according to "Conto Energia”

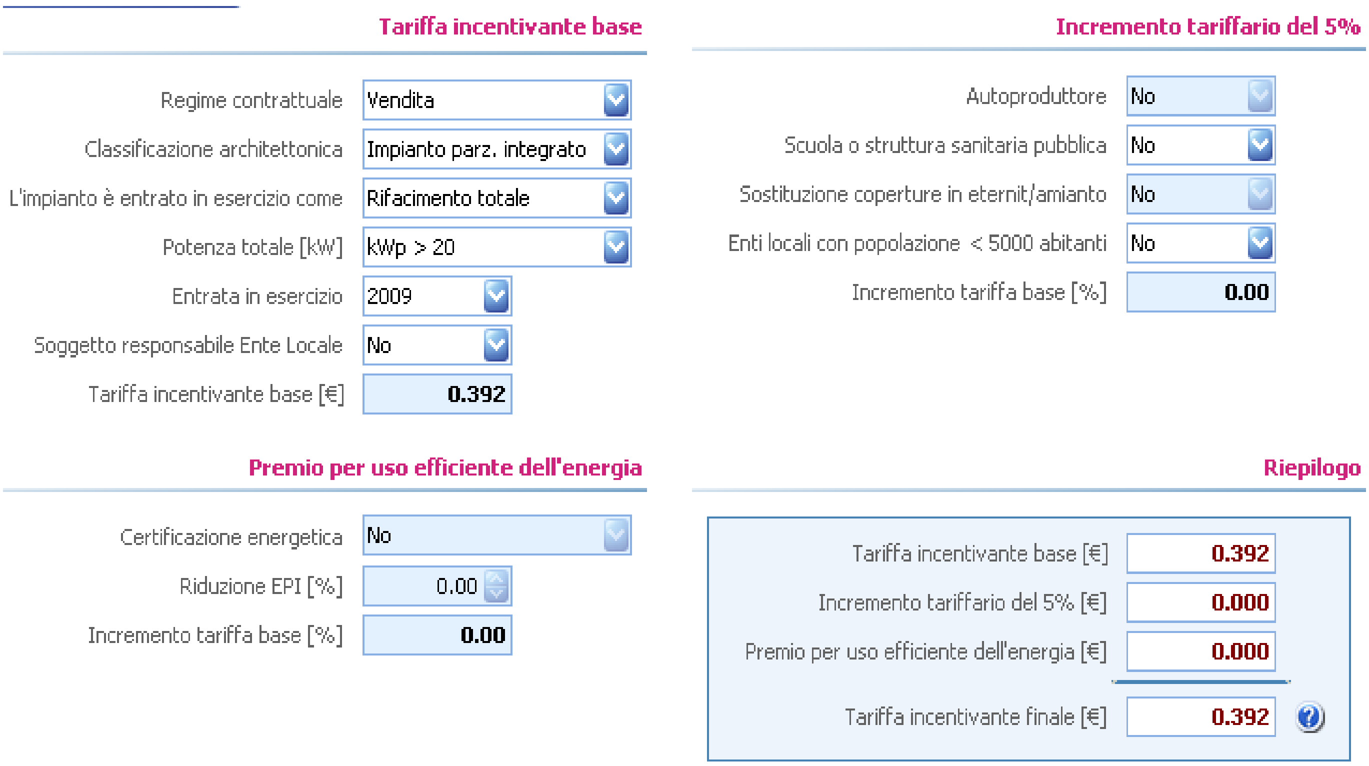
- AUTOPRODUCER, D. Lgs. n. 79, 16-03-99 art2, paragraph:2, The increase is recognized if the natural or juridical person who produces electric power uses it in measure not lower than 70 % per year for just use.
- SCHOOL OR SANITARY PUBLIC STRUCTURE: The increase is recognized in case of public or equal school of any order and degree.
- SUBSTITUTION COVERAGES IN ETERNIT / ASBESTOS: If it´s integrated totally in external surfaces of building wrappers, facts, construction structures of agricultural destination, in substitution of coverages in eternit or in any case continent asbestos.
- Local entities with population <5000 inhabitants.

As a result the the increase tariff bases is: 0 %

- PRIZE FOR EFFICIENT USE DELL ENERGY ENERGETIC CERTIFICATION: The PV operating facilities in Exchange regime on the site can benefit from an additional prize for efficient use dell energy
- REDUCTION EPI (%:), where this Environmental Performance Index (EPI) is a method of

quantifying and numerically benchmarking the environmental performance of a country's policies. And the EPI uses outcome-oriented indicators, then working as a benchmark index that can be more easil y used by policy makers, environmental scientists, advocates and the general public.

- The object of this study will be of eliminating the damages that the construction of the facilities could cause, as well as obtain the opportune favorable report of Energy and Environment of Lombardia, in order to obtain the corresponding Administrative authorization of the Headquarter of and the construction license.



4.5 .IDENTIFICATION AND ASSESSMENT OF IMPACTS

The environmental issues that are considered most relevant for PV power systems were identified in the workshop as well as the approaches that may be used to investigate them. The main environmental issues discussed at the workshop were:

- **Energy use**. Resource depletion. For example, the resource availability for indium (used in CIS-modules) and silver (used in mc-Si modules) has been indicated as potentially problematic.
- **Climate change**. Greenhouse gas emissions (notably CO 2) mostly originate from energy use and the potential for PV power systems to reduce these emissions is receiving increasing attention.
- **Land use**; at least in the case of ground-based arrays.
- **Health and Safety.** Continuous or accidental releases of hazardous materials can pose a risk towards workers and the public.
- **Waste.**
- **Atmosphere:** Weather conditions in the area where the works carried out will be altered during the construction phase (but not during the operational phase), especially in regard to air quality and the situation phonics.
- **Vegetation:,**This is another environmental factor that will be affected by the project, albeit in a testimonial, because the presence of natural vegetation is almost nonexistent.
- **Wildlife:** The works will affect the living conditions of certain species of fauna, but as urban area is not found.
- **Landscape:** The environment of the area perceptual perhaps may be one of the most affected by the works, introduction of foreign elements in the area.
- **Human environment:** Also the socio-economy will be influenced.

4.5.1. SUMMARY OF IMPACTS

To carry out the assessment of the impacts identified previously used names and classifications established by current legislation, which are:

- *Environmental impact compatible*: The one whose recovery is immediate after the cessation of the activity, but not necessary protective and remedial practices.
  Moderate environmental impact: He whose recovery requires no protective or remedial intensive practice, and in which the achievement of the initial environmental conditions takes time.
- *Severe environmental impac*t: One in which the recovery of environmental conditions requires the adequacy of protective or remedial measures, and in which, even with these measures, that recovery requires a lengthy period of time.
  *Critical environmental impac*t: one whose magnitude is greater than the acceptable threshold. With him there is a permanent loss of quality of environmental conditions, without possible recovery even with the adoption of protective or remedial measures.

The following table gathers the different impacts identified and valued previously for each of the environmental factors and in both phases of the project, where in conclusion will be generally compatible:

ENVIROMENTAL FATOR		CONSTRUCTION PHASE	OPERATION PHASE
Climate		NULL	NULL
Atmosphere	Atmosphere pollution	COMPATIBLE	VERY POSITIVE
	Situation phonics	COMPATIBLE	COMPATIBLE
Hydrography		NULL	NULL
Vegetation		COMPATIBLE	NULL
Fauna		COMPATIBLE	NULL
Natural and protected space		NULO	NULL
Landscape		MODERATE	MODERATE
Land use		COMPATIBLE	COMPATIBLE
Socioeconomic		VERY POSITIVE	VERY POSITIVE
Cultural patrimony		NULL	NULL

4.5.2 SYNTHESIS

Renewable energy can also have negative environmental and social consequences if implemented without prior planning and without providing real savings policies.
Therefore, the national and European legislation defines a very explicit way each of the actions, with the clear objective to avoid any environmental impact and minimize the atmospheric emission of pollutants.

The signing of the Kyoto Protocol and the Renewable Energy Plan (PER) reflects the commitment made by the Italian authorities as regards the reduction of GHG's emissions, particularly CO_2.

4.6. CALCULATION THE POLLUTION EMISSIONS AVOIDED

According to the lifetime of the installation: 25 years, its losses each year and the installed power 42.773 kWh, thans the programs Solarius PV: that use the information from reliable source : ENEL 2006 with its variation to 2009 and knowing that:

- TEP: is a commonly used conventional unit in the "energetic bilancio" to express in a common unit of measurement for all energy sources.

We can obtain the emissions of CO_2, SOx and other pollutants that would be avoided thanks to the implementation of photovoltaic systems

Dati Generali

Energia totale annua [kWh]	42 773.37	Perdita di efficienza [%]	0.80
Tempo di vita dell'impianto [anni]	25		

Attenzione per l'ambiente

Fonte dei dati: Rapporto ambientale ENEL 2006

	CO_2	SO_2	NO_x	Polveri
Emissioni specifiche in atmosfera [g/kWh]	496.0	0.93	0.58	0.029
Emissioni evitate in un anno [Kg]	21 215.59	39.78	24.81	1.24
Emissioni evitate in 25 anni [Kg]	476 871.69	894.13	557.63	27.88

Risparmio sul combustibile

Fonte dei dati	Articolo 2, comma 3, dei decreti ministeriali 20 luglio 2004
Fattore di conversione MWh in TEP [TEP/MWh]	0.22
TEP risparmiate in un anno	9.41
TEP risparmiate in 25 anni	211.52

Finally This would save 21,216 tCO_2 ,39,78 tSO_2 and 24, 81 $tN0_X$ per year

CHAP V

APPENDIX

CHAP V: APPENDIX

5. APPENDIX

The PV fittings and the relative components must respect, where of pertinence, the contained prescriptions in the following norms of reference, inclusive possible variations, updatings and extensions subsequently emanated by the organisms of th aforementioned lays.

They apply besides the technical documents emanated by the managers of net bringing application dispositions for the connection of PV fittings connected to the electric net and the prescriptions of local authority, inclusive those of the VVFFs.

5.1. LAWS AND DECREES

5.1.1. GENERAL NORMATIVE

Law March 1 st 1968, n. 186: dispositions pertaining to the production of materials, equipments, machineries, installation and electric and electronic fittings.

Law January 9 th 1991, n. 10: norm for the realization of the national energetic plan in subject of national use of the energy, of energetic saving and of development of the renewable sources of energy.

Decree Legislative 16 March 1999, n. 79: realization of the directive 96/92/CE bringing common norms for the inside market of the electric energy.

I decree Office of the environment 22 December 2000: financing to the communes for the realization of PV solar buildings to architectural high value.

Directive Us September 27 th 2001, n. 77: on the promotion of the electric energy produced by renewable energetic sources in the market of the electricity (2001/77/CE).

Legislative decree n. 387 of 29-12 -2003: realization of the directive 2001/77/CE related to the promotion of the electric energy produced by renewable energetic sources in the inside market of the electricity.

I decree Office of the Productive Activities 20 July 2004: new individualization of the quantitative objectives:

for the increase of the energetic efficiency in the final uses of energy, to the senses of the art. 9, paragraph 1, of the decree legislative 16 March 1999, n. 79.

of the national quantitative objectives of energetic saving and development of the renewable sources, of which to the art. 16, paragraph 4, of the decree legislative 23 May 2000, n. 164.

Law August 23 rd 2004, n. 239: I rearrange some energetic sector, as well as delegation to the Government for the rearrangement of the dispositions in force in subject of energy.

Legislative decree n. 192 of 19-08 -2005: realization of the directive 2002/91/CE related to the energetic output in the housebuilding.

Law December 27 th 2006, n. 296: dispositions for the formation of the annual budget and multi-year of the state (financial Law 2007).

Legislative decree n. 311 of 29-12 -2006: corrective and integrative dispositions to the decree legislative 19 August 2005, n. 192, bringing realization of the directive 2002/91/CE, related to the energetic output in the housebuilding.

5.1. 2. SAFETY

- *DPR 547/55 - D.Lgs. 626/94 and following modifications and integrations:* safety and prevention of the accidents on the job;

- *Law 46/90 - DPR 447/91 and following modifications and integrations:* electric safety.

5.1.3. NEW ACCOUNT ENERGY

- *Decree 19-02 -2007:* criterions and formality to stimulate the production of electric energy through photovoltaic conversion of the solar source, in realization of the article 7 of the decree legislative 29 December 2003, n. 387.

- *Law December 24 th 2007, n. 244 (financial law 2008):* dispositions for the formation of the annual budget and multi-year of the State (financial law 2008).

- *Technical norms CEI 64 -8*: you install not voters superior nominal voltage user to 1000 V in alternating current and to 1500 V in direct current.

5.1.4. TECNICHAL NORMATIVE

- *CEI 11 -20:* fittings of production of electric energy and groups of continuity connected to nets of The and II category.

- *CEI EN 60904-1 (CEI 82 -1)*: Parts 1: Measure of the characteristic PV voltage-current.

- *CEI EN 60904-2 (CEI 82 -2*): Part 2: Prescription for the PV cells of reference.

- *CEI EN 60904-3 (CEI 82 -3):* Part 3: Principles of measure for solar systems fotovoltaici for terrestrial use and ghostly irraggiamento of reference.

- *CEI EN 61727 (CEI 82 -9)*: PV systematize - Characteristics of the interface of link with the net.

- *CEI EN 61215 (CEI 82 -8):* PV modulate in crystalline silicon for terrestrial applications. Qualification of the project and homologation of the type.

- *CEI EN 50380 (CEI 82 -22)*: informative sheets and data of plate for PV installations

- *CEI 82 -25:* it drives to the realization of systems of PV generation connected to the electric nets of Average and Low Voltage

- *CEI EN 62093 (CEI 82 -24)*: component of PV systems - excluded (BOS) installations - Qualification of project under natural environmental conditions.

- *CEI EN 61000-3-2 (CEI 110 -31):* electromagnetic (EMC) compatibility - Part 3: Limits - Section 2: Limits for the issues of harmonic tide.

- CEI EN 60555-1 (CEI 77 -2): you disturb in the nets of feeding produced by instruments appliances and from similar electric equipments - Part 1: Definitions.

5.1.5. SERIES COMPOSED FROM

- *CEI EN 60439-1 (CEI 17-13/1):* subject equipments to tests type and (AS) subject equipments partially to tests type (ANS).

- *CEI EN 60439-2 (CEI 17-13/2*): particular prescriptions for the ducts bars.

- *CEI EN 60439-3 (CEI 17-13/3):* particular prescriptions for equipments assiemate of protection and manoeuvre destined to be installed in places where personal not trained it has access to their use - Pictures of distribution (ASD).

- *CEI EN 60445 (CEI 16 -2)*: you begin base and safety for the interface man-car, marcatura and identification - Individualization of the clamps and the instruments and of the extremities of the designate conductors and general rules for an alphanumeric system.

- *CEI EN 60529 (CEI 70 -1):* degrees of protection of the wraps (code IP).

- *CEI EN 60099-1 (CEI 37 -1*): unloaders - Part 1: Resistors non linear unloaders with spinterometri for systems to alternating current.

- *CEI 20 -19:* isolated cables with rubber with superior nominal tension not to 450/750 V.

- *CEI 20 -20:* isolated cables with polivinilcloruro with superior nominal tension not to 450/750 V.

- *CEI EN 62305 (CEI 81 -10):* protection against the lightnings.

- *CEI EN 62305-1CEI 81-10/1):* you begin general.

- *CEI EN 62305-2 (CEI 81-10/2):* evaluation of the risk.

- *CEI EN 62305-3 (CEI 81-10/3):* gives material to the structures and danger for the people.

- *CEI EN 62305-4 (CEI 81-10/4):* you install voters and electronic insides to the structures.

- *CEI 81 -3:* middle values of the number of lightnings to earth for year and for km^2

- *CEI 0 -2:* guide for the definition of the documentation of project for electric fittings.

- *CEI 0 -3:* guide for the compilation of the declaration of conformity and relative enclosures for the law n. 46/1990.

- *ONE 10349:* heating and raffrescamento of the buildings. Climatic data.

- *CEI EN 61724 (CEI 82 -15)*: relief of the performances of the PV systems- Lines it drives for the measure, I exchange him/it and the analysis of the data.

- *CEI 13 -4: s*ystems of measure of the electric energy - Composition, precision and verification.

- *CEI EN 62053-21 (CEI 13 -43):* apparatuses for the measure of the electric energy (c.to.) - Particular prescriptions - Part 21: Static counters of active energy (class 1 and 2).

- *EN 50470-1 and EN 50470-3* in progress of national recepimento near CEI.

- *CEI EN 62053-23 (CEI 13 -45):* apparatuses for the measure of the electric energy (c.to.) - Particular prescriptions - Part 23: Static counters of reactive energy (class 2 and 3).

- *CEI 64-8, part 7, section 712: PV* solar systematize of feeding.

5.2. DELIBERATIONS AEEG

- *Deliberation AEEG September 14 th 2005, n. 188/05* : definition of the subject attuatore and the formalities for the disbursement of the rates stimulating of thePV fittings, in realization of the art. 9 of the Decree of the Office of the productive Activities, of concert with the office of the environment and the guardianship of the territory, 28 July 2005.

- *AEEG deliberates February 10 th 2006 n. 28/06: t*echnical-economic conditions of the service of exchange on the place of the electric energy produced by fittings fed not by renewable sources of superior nominal power to 20 kVs, to the senses of the article 6 of the decree legislative 29 December 2003, n. 387.

- *AEEG deliberates February 24 th 2006 n. 40/06 and November 28 th 2006 n. 260/06:* modification and integration to the deliberation of the authority for the electric energy and the gas September 14 th 2005.

- A*EEG deliberates April 11 th 2007 n. 88/07:* dispositions in subject of measure of the electric energy produced by fittings of generation.

- *AEEG deliberates April 11 th 2007 n. 89/07*: you condition technical economic for the connection of fittings of production of electric energy to the electric nets with obligation of connection of bystanders to smaller or equal nominal tension to 1 kV.

- *AEEG deliberates April 11 th 2007 n. 90/07:* realization of the decree of the minister of the economic development, of concert with the minister of the environment and the guardianship of the territory and the sea February 19 th 2007, to the goals of the incentive of the production of electric energy through PV fittings.